County of Champaign, Illinois
1776 East Washington
Urbana, IL 61802
Ph 217.384.3720

METCAD BUILDING MECHANICAL ELECTRICAL UPGRADES

AT

1905 EAST MAIN STREET
URBANA, ILLINOIS 61802

FOR

COUNTY OF CHAMPAIGN
URBANA, ILLINOIS 61802

PROJECT MANUAL
ITB #2020-001

November 27, 2019

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County of Champaign, Illinois
1776 East Washington
Urbana, IL 61802
Ph 217.384.3720

February 7, 2018

BID: County of Champaign, Illinois
Satellite Jail Domestic Hot Water System Replacement
Friday, Dec 20th, 2019
2:00 P.M., Public Opening
Lyle Shields Conference Room
Brookens Administrative Center
1776 East Washington
Urbana, Illinois 61802-4581

Dear Bidder:

The County of Champaign is inviting the submission of sealed bids for HVAC and electrical upgrades at 1905 E. Main Street Urbana, IL 61802.

Specifications are prepared with the intent of offering equal opportunity to all bidders. No oral interpretations will be given to any bidder as to the meaning of the specifications. Requests for clarification must be submitted **in writing** via mail, fax or email to:

GHR Engineers and Associates, Inc.
Attn.: Sophie Hall
1615 South Neil Street
Champaign, IL 61820
Fax: (217) 356-1092
Email: shall@ghrinc.com

Clarification requests must be received no later than Wednesday, Dec 18th, 2019, 12:00 pm noon to be considered.

Pursuant to the Illinois Prevailing Wage Act (820 ILCS 130/1 et seq.), not less than the prevailing rate of wages as determined by the Illinois Department of Labor, County of Champaign, or court on review shall be paid by the vendor/contractor to all laborers, workers and mechanics performing work under this purchase order.

All bids are to be sealed and in the hands of the undersigned by the due date and time stated above, at which time bids will be publicly opened. There will be no bids accepted after said date and time. Your bid is to be submitted on the bid form provided. The envelope containing your bid is to be sealed and marked in the lower left-hand corner: **"Sealed Bid: Satellite Jail Domestic Hot Water System Replacement".** Bids will not be accepted by FAX mail.

County of Champaign, Illinois
1776 East Washington
Urbana, IL 61802
Ph 217.384.3720

The Champaign County Board reserves the right to reject any or all bids, to accept the bids, or to waive any irregularities should it deem to be in the best interest of the County of Champaign to do so. The bids will be awarded to the lowest responsible bidder meeting specifications as determined by the Champaign County Board.

Sincerely,

Dana Brenner
Facilities Director

END OF NOTICE TO BIDDERS 00 0200

DOCUMENT 00 1116 - INVITATION TO BID - #2020-001

1.1 PROJECT INFORMATION

A. Notice to Bidders: Qualified bidders are invited to submit bids for Project as described in this Document.

B. Project Identification:
HVAC and Electrical Upgrades

1. Project Location:

   1905 E. Main St.
   Urbana, IL 61802

C. Owner: County of Champaign

1. Owner's Representative:

   Dana Brenner, Facilities Director
   1776 East Washington
   Urbana, IL 61802-4581
   Phone: (217) 384-3765
   Fax: (217) 384-3896
   Email: dbrenner@co-champaign.il.us

D. Project Design Team: GHR Engineers and Associates, Inc.

E. Project Description:

1. Base Bid: Project consists of removal of (4) existing air cooled condensing units and replacement with R410A compatible units of same tonnage. Replacement of (2) blower coils with computer room cooling equipment and a mini split. Replacement of existing boilers with new condensing type boilers. Replacement of existing CAV AHU-3 and associated system with new VAV AHU-3. Various controls upgrades.
2. Alternate Bid No. 1: Replacement of AHU-2 and AHU-4 and associated condensing units.

F. Construction Contract: Bids will be received for the following Work:

   General Contract (all trades).

1.2 BID SUBMITTAL AND OPENING

A. Owner will receive sealed bids until the bid time and date at the location indicated below. Owner will consider bids prepared in compliance with the Contract Documents issued by Owner, and delivered as follows:

1. **Bid Date: Friday, December 20th, 2019**
2. **Bid Time: 2:00 p.m., local time.**

Location:

Lyle Shields Conference Room
Brookens Administration Center
1776 East Washington
Urbana, IL 61802

B. Bids will be thereafter opened in the presence of the bidders and read aloud.

1.3 BID SECURITY

A. Bid security in the form of a bank draft/cashier's check, certified check, U.S. money order, or bid bond **payable to County of Champaign** shall be submitted with each bid in the amount of **ten (10) percent** of the bid amount. No bids may be withdrawn for a period of **sixty (60) days** after opening of bids. Owner reserves the right to reject any and all bids and to waive informalities and irregularities.

1.4 PREBID CONFERENCE / SITE VISIT

A. A prebid conference for all bidders will be held at **Lyle Shields Conference Room, Brookens Administration Center, 1776 East Washington, Urbana, Illinois** on Thursday, February 22, 2018 at 2:00 pm, local time. Meet at front entrance. Prospective bidders are **required** to attend.

B. Building access for additional site visits may be made by contacting Owner's Representative.
Dana Brenner, Facilities Director
Phone: 217-384-3765
Fax: 217-384-3896
E-mail: dbrenner@co-champaign.il.us

1.5 DOCUMENTS

A. Documents can be procured by emailing Randy Feese, rfeese@ghrinc.com. All documents will be in pdf form by email only.

1.6 TIME OF COMPLETION

A. Bidders shall begin the Work on receipt of the Notice to Proceed and shall complete the Work within the Contract Time.

1. Anticipated Award of Contract: Board Meeting, Thursday, March 22, 2018.
2. Anticipated Letter of Notice of Award: On or about Friday, March 23, 2018.
3. Pre-Construction/Pre-Installation Meeting: TBD.
4. **Substantial Completion: Tuesday, July 31, 2018.**
5. Punch List: Issued on or about Friday, August 3, 2018.
6. **Final Completion: Friday, August 17, 2018.**

1.7 BIDDER'S QUALIFICATIONS

A. Bidders must be properly licensed under the laws governing their respective trades and be able to obtain insurance and bonds required for the Work. **A Performance Bond, a separate Labor and Material Payment Bond, and Insurance in a form acceptable to Owner will be required of the successful Bidder.**

END OF DOCUMENT 00 1116

DOCUMENT 00 2213 - SUPPLEMENTARY INSTRUCTIONS TO BIDDERS

~~1.1 SUPPLEMENTARY INSTRUCTIONS TO BIDDERS, GENERAL~~

~~A. The following supplements modify AIA Document A701, "Instructions to Bidders." Where a portion of the Instructions to Bidders is modified or deleted by these Supplementary Instructions to Bidders, unaltered portions of the Instructions to Bidders shall remain in effect.~~

~~1.2~~1.1 SUPPLEMENTARY INSTRUCTIONS TO BIDDERS - BIDDER'S REPRESENTATIONS

~~B.~~The Bidder has investigated all required fees, permits, and regulatory requirements of authorities having jurisdiction and has properly included in the submitted bid the cost of such fees, permits, and requirements not otherwise indicated as provided by Owner.

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~~B.~~A.

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~~B.~~1. Permit Application: Complete building permit application and file with authorities having jurisdiction within five days of the Notice of Ward.

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~~D.~~B. The Bidder is a properly licensed Contractor according to the laws and regulations of The State of Illinois and meets qualifications indicated in the Procurement and Contracting Documents.

~~E.~~C. The Bidder has incorporated into the Bid adequate sums for work performed by installers whose qualifications meet those indicated in the Procurement and Contracting Documents.

~~1.5~~1.2 BIDDING DOCUMENTS

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A. Interpretation or Correction of Procurement and Contracting Documents:

1. Submit Bidder's Requests for Interpretation as outlined in the Notice to Bidders.

B. Submit Requests for Substitution on form provided. Substitution requests shall be in advance of bid.~~accepted during bidding only.~~

~~B.~~

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C. Addenda:

~~2.~~Addenda may be issued at any time prior to the receipt of bids.

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~~1.~~2. Owner may elect to waive the requirement for acknowledging receipt of Addenda as follows:

~~1)~~a. Information received as part of the Bid indicates that the Bid, as submitted, reflects modifications to the Procurement and Contracting Documents included in an unacknowledged Addendum.

~~1)~~
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~~2)~~b. Modifications to the Procurement and Contracting Documents in an unacknowledged Addendum do not, in the opinion of Owner, affect the Contract Sum or Contract Time.

~~1.6~~1.3 BIDDING PROCEDURES

A. Preparation of Bids:

~~a.~~1. The Bid shall include unit prices when called for by the Procurement and Contracting Documents. Owner may elect to consider unit prices in the determination of award. Unit prices will be incorporated into the Contract.

~~a.~~2. Owner may elect to disqualify a bid due to failure to submit a bid in the form requested, failure to bid requested alternates or unit prices, failure to complete entries in all blanks in the Bid Form, or inclusion by the Bidder of any alternates, conditions, limitations or provisions not called for.

Retail sales tax will NOT be included in the bid amount. The Owner is exempted by Section 3 of the Illinois Use Tax Act (Section 3, House Bill 1610, approved July 31, 1961, Illinois Revised Statutes 1967, Chapter 120, Section 439.3) from paying any of the taxes imposed by the Act and sales to Owner are exempt by Section 2, House Bill 1609, approved July 31, 1961, Illinois Revised statutes 1967, Chapter

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120, Section 441) from any of the taxes imposed by the Act. The Department of Revenue of the State of Illinois under Rule No. 15, issued August 9, 1961, has declared that sales of materials to construction contractors for conversion into real estate for schools, governmental bodies, agencies and instrumentalities are not taxable retail sales. **The Contractor shall be responsible for any sales, consumer, use and similar taxes for the Work.**

3. ~~District~~ Owner is not responsible for any costs incurred by a Contractor in the preparation or delivery of bids. The Contractor shall be responsible for the actual delivery of bids during business hours to the address indicated. Any bid received after the delivery deadline will be disqualified.

4. ~~District~~ Owner reserves the right to obtain clarification of any point in a Contractor submittal or to obtain additional information.

~~5.~~ FOIA: As an independent Contractor of the District, records in the possession of the Contractor related to this Agreement may be subject to the Illinois Freedom of Information Act ("FOIA"), 5 ILCS 140/5-1 et seq.; 5 ILCS 140/7(2). The Contractor shall immediately provide the District with any such records requested by the District in order to timely respond to any FOIA request received by the District.

~~E.~~B. Subcontractors, Suppliers, and Manufacturers List Bid Supplement:

~~a.~~1. Provide list of major subcontractors, suppliers, and manufacturers furnishing or installing products no later than **ten (10) business days** following Notice to Proceed. Do not change subcontractors, suppliers, and manufacturers from those submitted without approval of Owner.

~~1.7~~1.4 CONSIDERATION OF BIDS

A. Rejection of Bids:

~~a.~~Owner reserves the right to reject a bid based on Owner's and Design Team's ~~Architect's~~ evaluation of qualification information submitted following opening of bids. Owner's evaluation of the Bidder's qualifications will include: status of licensure and record of compliance with licensing requirements, record of quality

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of completed work, record of Project completion and ability to complete, record of financial management including financial resources available to complete Project and record of timely payment of obligations, record of Project site management including compliance with requirements of authorities having jurisdiction, record of and number of current claims and disputes and the status of their resolution, and qualifications of the Bidder's proposed Project staff and proposed subcontractors.

~~1.6~~1.5 PERFORMANCE BOND AND PAYMENT BOND

A. Both a Performance Bond and a Payment Bond will be required, each in an amount equal to 100 percent of the Contract Sum.

B. The Bidder shall deliver the required bonds to Owner no later than **ten (10)** days after the date of Notice of Intent to Award and no later than the date of execution of the Contract, whichever occurs first. Owner may deem the failure of the Bidder to deliver required bonds within the period of time allowed a default.

C. Bonds shall be executed and be in force on the date of the execution of the Contract.

~~C.~~

~~1.7~~1.6 INSURANCE

A. The Contractor shall take all necessary precautions and exercise due caution so as not to damage the premises or properties of others. The Contractor's signature on the bid sheet certifies to the District that the Contractor has adequate insurance coverage for any vehicle that may be utilized in the delivery of products or materials on the District's property. The Contractor shall submit evidence, satisfactory to the District, that the Contractor has coverage of General Liability Insurance, Worker's Compensation Insurance, and Automobile Liability Insurance to the limits described below with companies licensed to do business in Illinois with an A.M. Best rating of A that is satisfactory to the District. The certificates of such insurance shall carry an endorsement to the effect that the Insurance Company will defend the District as a party in the event the successful bidder becomes a party to any litigation as a result of the activities of the Contractor, subcontractor, or any direct or indirect employee of same under the terms of this contract for injuries to property or person. Such policies shall name the District, its Board, Board members, employees, agents, and successors

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as an additional insured and provide that it is primary to, and not contributing with, any policy carried by Contractor covering the same loss with a waiver of subrogation in favor of the School District. The Contractor shall provide Certificates of Insurance for:

~~1.~~ Vehicular: It is required that the successful Contractor present to the District, before commencing delivery under this Contract, a Certificate of Insurance covering all vehicles that may be utilized. Said insurance is to provide a $1,000,000 combined single limit for bodily injury and property damage. All certificates shall indicate that the carrying company shall not cancel insurance coverage without giving Owner thirty (30) days written advance notification.

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2. Liability: It is required that the successful Contractor present to the District, **before commencing delivery under this Contract**, a Certificate of Insurance for which coverage is included for contractor liability, contingent liability, contractual liability, and product liability. Bodily injury and property damage limits of $1,000,000 occurrence and $2,000,000 aggregate. Said Certificate shall indicate that the carrying company shall not cancel insurance coverage without giving District thirty (30) days written advance notice.

3. Worker's Compensation: Statutory Limits.

~~1.8~~1.7 STANDARD CONTRACT CONDITIONS

A. This contract shall be governed in all aspects as to validity, construction, capacity, performance, or otherwise by the laws of the State of Illinois.

B. Contractors shall comply with the Civil Rights Act of 1964, as amended, all applicable State and Federal non-discrimination laws including but not limited to the Family and Medical Leave Act, the Americans with Disabilities Act, the Age Discrimination in Employment Act and shall comply with the provisions of the Illinois Human Rights Act.

C. Contractors shall not assign, transfer, convey, sublet, or otherwise dispose of this contract, including any or all of it right, title or interest therein, or its power to execute such contract to any person, company or corporation, without prior written consent of ~~Champaign Community Unit School District #4~~The County of Champaign.

D. By submitting a bid the Contractor certifies that the Contractor is not barred from bidding on this contract as a result of a violation of either the bid-rigging or bid-rotating provisions of Article 33E of the Criminal Code of 1961, as amended.

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By submitting a bid, the Contractor, having 25 or more employees, does hereby certify pursuant to Section 3 of the Illinois Drug-Free Workplace Act (30 ILCS 580/3) that it shall provide a drug-free workplace for all employees engaged in the performance of work under the contract by complying with the requirements of the Illinois Drug-Free Workplace Act and, further certifies, that it is not ineligible for award of this contract by reason of debarment for a violation of the Illinois Drug-Free Workplace Act.

E. By submitting a bid, the Contractor does hereby certify pursuant to Section 2-105 of the Illinois Human Rights Act (775 ILCS 5/2-105) that it has a written sexual harassment policy that includes, at a minimum, the following information: (i) the illegality of sexual harassment; (ii) the definition of sexual harassment under State law; (iii) a description of sexual harassment, utilizing examples; (iv) an internal complaint process including penalties; (v) the legal recourse, investigative and complaint process available through the Department of Human Rights and Human Rights Commission; (vi) direction on how to contact the Department of Human Rights and Human Rights Commission; and (vii) protection against retaliation.

~~1.9~~1.8 STATEMENT OF NON-DISCRIMINATION

A. The Illinois Human Rights Acts prohibits discrimination on the basis of: “race, color, religion, sex, national origin, ancestry, age, order of protection status, marital status, physical or mental disability, military status, sexual orientation, or unfavorable discharge from military service in connection with employment, real estate transactions, access to financial credit, and the availability of public accommodations.” It also prohibits sexual harassment and discrimination in employment on the basis of citizenship status.

1.9 PREVAILING WAGE

A. This contract calls for the construction of a “public work” within the meaning of the Illinois Prevailing Wage Act, 920 ILCS 130/.01. The Act requires contractors and subcontractors to pay al laborers, workers and mechanics performing services on public works projects no less than the “prevailing rate of wages” (hourly cash wages plus fringe benefits) in the county where the work is performed. Each Contractor and

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Subcontractor rendering services under this contract must comply with all requirements of this Act. Each Contractor and Subcontractor shall keep records of the prevailing wages paid to their employees, submit a monthly certified payroll to County of Champaign, and make such records available to County of Champaign for inspection upon seven business days notice.

B. For information regarding the current prevailing wage rates for Champaign County, Illinois can be found at:

http://www.illinois.gov/idol/laws-rules/conmed/pages/rates.aspx.

C. Prevailing Wage Rates change periodically. Contractor shall verify and revise the prevailing wages on a regular basis.

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1.10 FAILURE TO FULFILL CONTRACT

A. When any Contractor fails to provide a service or provides a service which does not conform to the specifications, County of Champaign ~~Champaign Community Unit School District #4~~ may, at its sole discretion, annul and set aside the contract entered into with said Contractor, either in whole or in part, and make and enter into a new contract for the same services in such manner as seems to County of Champaign ~~Champaign Community Unit School District #4~~ to be to its best advantage. Any failure to furnish services by reason of the failure of the Contractor, as stated above, shall be a liability against such Contractor and his sureties. County of Champaign ~~Champaign Community Unit School District #4~~ reserves the right to cancel, without penalty, any services which the successful Contractor may be unable to furnish because of economic conditions, governmental regulations or other similar causes beyond the control of the Contractor provided satisfactory proof is furnished to ~~Champaign Community Unit School District #4~~County of Champaign if requested.

B. Without Cause Termination: The County ~~District~~ may terminate its contract with the Contractor without cause after providing the Contractor with thirty (30) days written notice.

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1.11 EXECUTION OF THE CONTRACT

A. Subsequent to the Notice of Intent to Award, and within **ten (10) business days** after the prescribed Form of Agreement is presented to the Awardee for signature, the Awardee shall execute and deliver the Agreement to Owner through Architect, in such number of counterparts as Owner may require.

B. Owner may deem as a default the failure of the Awardee to execute the Contract and to supply the required bonds and insurance when the Agreement is presented for signature within the period of time allowed.

~~A.~~

~~B. Owner may deem as a default the failure of the Awardee to execute the Contract and to supply the required bonds and insurance when the Agreement is presented for signature within the period of time allowed.~~

C. Unless otherwise indicated in the Procurement and Contracting Documents of the executed Agreement, the date of commencement of the Work shall be the date of the executed Agreement.

In the event of a default, Owner may declare the amount of the Bid security forfeited and elect to either award the Contract to the next responsible bidder or re-advertise for bids.

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1.12 INDEMNITY

A. To the fullest extent permitted by law, Contractor shall indemnify and hold harmless the Owner from and against claims, damages, losses and expenses, including but not limited to attorney's fees, arising out of or resulting from performance of the work provided that such claim, damage, loss or expense is attributable to bodily injury, sickness, disease or death, or to injury to or destruction of tangible property, but only to the extent caused by the negligent acts or omissions of the Contractor, a subcontractor, anyone directly or indirectly employed by them or anyone for whose acts they may be liable, regardless of whether or not such claim damage, loss or expense is caused in part by a party indemnified hereunder.

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DOCUMENT 00 3119 - EXISTING CONDITION INFORMATION

1.1 EXISTING CONDITION INFORMATION

A. This Document with its referenced attachments is part of the Procurement and Contracting Requirements for Project. They provide Owner's information for Bidders' convenience and are intended to supplement rather than serve in lieu of the Bidders' own investigations. They are made available for Bidders' convenience and information, but are not a warranty of existing conditions. This Document and its attachments are not part of the Contract Documents.

B. Photographic report of existing conditions that includes photographic documentation on existing conditions is appended to this Document.

END OF DOCUMENT 00 3119

DOCUMENT 00 4113 - BID FORM - STIPULATED SUM (SINGLE-PRIME CONTRACT)

1.1 BID INFORMATION

A. Bidder: ____.

B. Project Name: **Satellite Jail Domestic Hot Water System Replacement**

C. Project Location: Champaign County Satellite Jail
502 South Lierman Avenue
Urbana, Illinois 61802

D. Owner: County of Champaign

E. Building Design Team: GHR Engineers and Associates, Inc.

1.2 CERTIFICATIONS AND BASE BID

~~1.~~A. Base Bid, Single-Prime (All Trades) Contract: The undersigned Bidder, having carefully examined the Procurement and Contracting Requirements, Conditions of the Contract, Drawings, Specifications, and all subsequent Addenda, as prepared by the Design Team, having visited the site, and being familiar with all conditions and requirements of the Work, hereby agrees to furnish all material, labor, equipment and services, including all scheduled allowances, necessary to complete the construction of the above-named project, according to the requirements of the Procurement and Contracting Documents, for the stipulated sum of:

1. ____Dollars ($______________).

Bidders Note: Show bid amount in both words and figures. All spaces must be completed.

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1.3 BID GUARANTEE

~~1.~~A. The undersigned Bidder agrees to execute a contract for this Work in the above amount and to furnish surety as specified within **ten (10)** days after a written Notice of Award, if offered within **sixty (60)** days after receipt of bids, and on failure to do so agrees to forfeit to Owner the attached bank draft/cashier's check, certified check, U.S. money order, or bid bond **payable to County of Champaign**, as liquidated damages for such failure, in an amount constituting **ten percent (10%)** of the Base Bid amount:

1. ____Dollars ($______________).

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B. In the event Owner does not offer Notice of Award within the time limits stated above, Owner will return to the undersigned the bank draft/cashier's check, certified check, U.S. money order, or bid bond.

C. The Owner reserves the right to accept or not accept Alternate Bids P-1 and P-2 in whatever order best serves the County's needs.

~~1.5~~1.4 TIME OF COMPLETION

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A. The undersigned Bidder proposes and agrees hereby to commence the Work of the Contract Documents on a date specified in a written Notice to Proceed to be issued by Owner, and shall fully complete the Work as indicated in the Invitation to Bid.

~~1.6~~1.5 ACKNOWLEDGEMENT OF ADDENDA

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A. The undersigned Bidder acknowledges receipt of and use of the following Addenda in the preparation of this Bid:
   1. Addendum No. 1, dated ____________________.
   2. Addendum No. 2, dated ____________________.
   3. Addendum No. 3, dated ____________________.

~~1.8~~1.6 CONTRACTOR'S LICENSE

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A. The undersigned warrants that he/she is duly authorized to bind contractually the entity submitting this bid, to fully perform all duties and to deliver all services in accordance with the terms and conditions set forth herein. All signatures to be sworn before a Notary Public.

~~1.9~~1.7 SUBMISSION OF BID

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Respectfully submitted this ____ day of ____________, 2018.

Submitted By: ________________________________
(Name of bidding firm or corporation)

Authorized Signature: ________________________________
(Handwritten signature)

Signed By: ________________________________
(Type or print name)

Title: ________________________________
(Owner/Partner/President/Vice President)

Witness By: ________________________________
(Handwritten signature)

Attest: ________________________________
(Handwritten signature)

By: ________________________________
(Type or print name)

Subscribed and sworn to before me this

______Day of ____________________, 2018.

_________________________________, Notary Public

(Affix Notary Seal Here)

END OF DOCUMENT 00 4113

DOCUMENT 00 4313 - BID SECURITY FORMS

1.1 BID FORM SUPPLEMENT

A. A completed bid bond form is required to be attached to the Bid Form.

1.2 BID BOND FORM

A. AIA Document A310, "Bid Bond," is the recommended form for a bid bond. A bid bond acceptable to Owner, is required to be attached to the Bid Form as a supplement.

B. Copies of AIA standard forms may be obtained from The American Institute of Architects; www.aia.org/contractdocs/purchase/index.htm; email: docspurchases@aia.org; (800) 942-7732.

END OF DOCUMENT 00 4313

SECTION 01 1000 - SUMMARY

PART 1 - GENERAL

1.1 PROJECT INFORMATION

A. Project Identification: **METCAD Building HVAC and Electrical Upgrades**

1. Project Location:

Champaign County Satellite Jail
502 South Lierman Avenue
Urbana, Illinois 61802

B. Owner: County of Champaign

C. Design Team: GHR Engineers and Associates, Inc.

D. Project Description:

1. Base Bid: Project consists of removal of existing water heaters, master thermostatic mixing valve and associated water piping. Installation of new water heaters, master thermostatic mixing valve and associated piping. Installation of new hot water return piping in Staff Administration Area. Work shall be scheduled so as to have a hot water outage for a maximum of eight (8) hours.
2. Alternate Bid No. 1: New water waste management system for cell combi-units.

1.2 WORK RESTRICTIONS

Contractor's Use of Premises: During construction, Contractor will have limited use of site and building indicated. Contractor's use of premises is limited only by Owner's right to perform work or employ other contractors on portions of Project and as follows:

1. Owner will occupy premises during construction. Perform construction only during normal working hours 8 AM to 5 PM Monday thru Friday, other than holidays, unless otherwise agreed to in advance by Owner. Clean up work areas and return to usable condition at the end of each work period.
2. Limits: Limit site disturbance.
3. Driveways, Walkways, and Entrances: Keep driveways, loading areas, and entrances serving premises clear and available to Owner, Owner's employees,

and emergency vehicles at all times. Do not use these areas for parking or storage of materials.

B. On-Site Work Hours: Limit work in the existing building to normal business working hours of 8 AM to 5 PM, Monday through Friday, unless otherwise indicated.

1. Weekend Hours: As permitted by Owner. Coordinate with Owner.
2. Early Morning Hours: 7 AM or as permitted by Owner. Coordinate with Owner.

C. Nonsmoking Building: Smoking is not permitted within the building or on the project site.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION (Not Used)

END OF SECTION 01 1000

SECTION 01 2000 - PRICE AND PAYMENT PROCEDURES

PART 1 - GENERAL

1.1 PAYMENT PROCEDURES

A. Submit a Schedule of Values at least **seven (7)** days before the initial Application for Payment. Break down the Contract Sum into at least one line item for each Specification Section in the Project Manual table of contents. Coordinate the schedule of values with Contractor's construction schedule.

1. Arrange schedule of values consistent with format of AIA Document G703.
2. Round amounts to nearest whole dollar; total shall equal the Contract Sum.
3. Provide a separate line item in the schedule of values for each part of the Work where Applications for Payment may include materials or equipment purchased or fabricated and stored, but not yet installed.
4. Provide separate line items in the schedule of values for initial cost of materials and for total installed value of that part of the Work.
5. Provide a separate line item in the schedule of values for each allowance.

B. Application for Payment Forms: Use AIA Document G702 and AIA Document G703 forms for Applications for Payment.

1. Anticipated Application for Payment Schedule:

a. Application for Payment No. 01: once material is delivered to project site
b. Application for Payment No. 02: upon completion of installation
c. Application for Payment No. 03: Final payment upon completion of punch list, receipt of all close-out documents and completion of owner training

C. Submit **three (3)** copies of each application for payment according to the schedule established in Owner/Contractor Agreement.

1. Notarize and execute by a person authorized to sign legal documents on behalf of Contractor.
2. With each Application for Payment, Contractor shall include the Contractor’s waiver of lien for the full amount and partial waivers of mechanic's liens from subcontractors, sub-subcontractors, and suppliers for construction period covered by the previous application.

3. Submit final Application for Payment with or preceded by conditional final waivers from every entity involved with performance of the Work covered by the application who is lawfully entitled to a lien.

   a. Include insurance certificates, proof that taxes, fees, and similar obligations were paid, and evidence that claims have been settled.
   b. Include affidavit of payment of debts and claims on AIA Document G706.
   c. Include affidavit of release of liens on AIA Document G706A.
   d. Include consent of surety to final payment on AIA Document G707.

4. Certified Payroll Statements: The Contractor shall submit Certified Payroll Statements pursuant to Illinois Law-Public Act 94-0515 with each payment application. The *Certified Transcript of Payroll* statement forms are available through the Illinois Department of Labor website: http://www.state.il.us/agency/idol/forms/pdfs/IL452CM02.pdf. Certified payroll statements are required from the Contractor and each Subcontractor. The statements are to include the time period of the payment application. Payment Applications will not be processed without accompanying Certified Payroll Statements.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION (Not Used)

END OF SECTION 01 2000

SECTION 01 2500 - SUBSTITUTION PROCEDURES

PART 1 - GENERAL

1.1 SUBSTITUTION PROCEDURES

A. Substitutions include changes in products, materials, equipment, and methods of Contractor.

B. Substitution Requests: Identify product or fabrication or installation method to be replaced. Include Specification Section number and title and Drawing numbers and titles. Substitutions will NOT be considered after bidding.

1. Substitution Request Form: Use facsimile of form provided in the Project Manual.
2. Submit requests by **noon on Monday, December 18, 2018**.
3. Identify product to be replaced and show compliance with requirements for substitutions. **Include a detailed comparison of significant qualities of proposed substitution with those of the Work specified**, a list of changes needed to other parts of the Work required to accommodate proposed substitution, and any proposed changes in the Contract Sum or the Contract Time should the substitution be accepted.
4. Documentation: Show compliance with requirements for substitutions and the following, as applicable:

    a. Statement indicating why specified product or fabrication or installation cannot be provided, if applicable.
    b. Coordination information, including a list of changes or revisions needed to other parts of the Work and to construction performed by Owner and separate contractors that will be necessary to accommodate proposed substitution.
    c. Detailed comparison of significant qualities of proposed substitution with those of the Work specified. Include annotated copy of applicable Specification Section. Significant qualities may include attributes such as performance, weight, size, durability, visual effect, sustainable design characteristics, warranties, and specific features and requirements indicated. **Indicate deviations, if any, from the Work specified.**
    d. Product Data, including drawings and descriptions of products and fabrication and installation procedures.

e. Samples, where applicable or requested:

1) All samples shall be clearly labeled with product information and Vendor contact information.

f. Certificates and qualification data, where applicable or requested.
g. List of similar installations for completed projects with project names and addresses and names and addresses of architects and owners.
h. Material test reports from a qualified testing agency indicating and interpreting test results for compliance with requirements indicated.
i. Research reports evidencing compliance with building code in effect for Project.
j. Detailed comparison of Contractor's construction schedule using proposed substitution with products specified for the Work, including effect on the overall Contract Time. If specified product or method of construction cannot be provided within the Contract Time, include letter from manufacturer, on manufacturer's letterhead, stating date of receipt of purchase order, lack of availability, or delays in delivery.
k. Cost information, including a proposal of change, if any, in the Contract Sum.
l. Contractor's certification that proposed substitution complies with requirements in the Contract Documents except as indicated in substitution request, is compatible with related materials, and is appropriate for applications indicated.
m. Contractor's waiver of rights to additional payment or time that may subsequently become necessary because of failure of proposed substitution to produce indicated results.

C. Architect will review proposed substitutions and notify Contractor of their acceptance or rejection via Addendum. If necessary, Architect will request additional information or documentation for evaluation.

1. Use product specified if Architect does not issue a decision on use of a proposed substitution within time allocated.

D. Do not submit unapproved substitutions on Shop Drawings or other submittals.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION (Not Used)

END OF SECTION 01 2500

County of Champaign, Illinois
1776 East Washington
Urbana, IL 61802
Ph217.384.3720

SUBSTITUTION REQUEST FORM

Project: METCAD Building
HVAC and Electrical Upgrades

Request No.:

Date:

Location (provide room number(s):

Name of Material, Product or Equipment item specified:

Name of Material, Product or Equipment item submitted as substitution:

Specification Section:

Qualities that differ from specified product or system:

Name of Manufacturer / Fabricator:

Address

City, State and Zip

Phone:

Name of Vendor / Supplier Requesting Change	Address	Contact Name	Phone:

Reason for requesting substitution request:

Substitution affects other materials or systems, such as dimensional revisions, redesign of structure or modifications to other work:

_______NO

_______YES; describe requirements:

If substitution requires modifications to dimensions indicated on drawings, are such modifications clearly indicated on attached data?

_______YES

_______NO; if NO, explain:

Substitution has an affect on Construction Schedule:

_______NO

_______YES; describe affect on schedule:

Savings or Credit to Contract Amount for accepting substitute:

____Dollars ($_______________).
Note: Show bid amount in both words and figures.

The attached data is furnished herewith for evaluation of the substitution:

_______Product Data _______Drawings _______Samples _______Tests _______Reports

_______Other Information; describe:

The undersigned hereby certifies:

1. The proposed substitution has been fully investigated and is equal or superior to specified product.
2. The same or better warranty will be furnished for proposed substitution as for specified material, product or equipment.
3. All changes in the work resulting from the use of this substitution, if approved, will be coordinated and completed in all respects and all costs, including, but not limited to, those for additional services rendered by the Owner are the responsibility for this Contractor at no additional cost to the Contract.

____ ____
Contractor Signed by

____
Address

____
City, State and Zip

END OF SUBSTITUTION FORM 01 2500a

SECTION 01 2600 - CONTRACT MODIFICATION PROCEDURES

PART 1 - GENERAL

1.1 CONTRACT MODIFICATION PROCEDURES

A. Design Team will issue supplemental instructions authorizing minor changes in the Work, not involving adjustment to the Contract Sum or the Contract Time.

B. Owner-Initiated Proposal Requests: Design Team will issue a detailed description of proposed changes in the Work.

1. Proposal Requests are not instructions either to stop work in progress or to execute the proposed change.
2. Within time specified in Proposal Request or 20 days, when not otherwise specified, after receipt of Proposal Request, submit a quotation estimating cost adjustments to the Contract Sum and the Contract Time.

C. Contractor-Initiated Proposals: If latent or changed conditions require modifications to the Contract, Contractor may initiate a claim by submitting a request for a change to Design Team.

D. On Owner's approval of a Proposal Request, Design Team will issue a Change Order for signatures of Owner and Contractor, for all changes to the Contract Sum or the Contract Time.

E. Design Team may issue a Construction Change Directive. Construction Change Directive instructs Contractor to proceed with a change in the Work, for subsequent inclusion in a Change Order.

1. Construction Change Directive contains a complete description of change in the Work. It also designates method to be followed to determine change in the Contract Sum or the Contract Time.

F. Documentation: Maintain detailed records on a time and material basis of work required by the Construction Change Directive. After completion of change, submit an itemized account and supporting data necessary to substantiate cost and time adjustments to the Contract.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION (Not Used)

END OF SECTION 01 2600

SECTION 01 3000 - ADMINISTRATIVE REQUIREMENTS

PART 1 - GENERAL

1.1 PROJECT MANAGEMENT AND COORDINATION

A. Subcontract List: Submit a written summary identifying individuals or firms proposed for each portion of the Work.

B. Key Personnel Names: Within ten (10) days of starting construction operations, submit a list of key personnel assignments, including superintendent and other personnel in attendance at Project site. List e-mail addresses and telephone numbers.

C. Coordinate construction operations included in different Sections of the Specifications to ensure efficient and orderly installation of each part of the Work.

D. Requests for Information (RFIs): On discovery of the need for additional information or interpretation of the Contract Documents, Contractor shall prepare and submit an RFI. Use forms acceptable to Design Team and Owner.

E. Schedule and conduct (2) progress meetings at Project site, coordinated with the Design Team and Owner. **Notify Owner of meeting dates and times.** Require attendance of each subcontractor or other entity concerned with current progress or involved in planning, coordination, or performance of future activities.

1.2 SUBMITTAL ADMINISTRATIVE REQUIREMENTS

A. Coordinate each submittal with fabrication, purchasing, testing, delivery, other submittals, and related activities that require sequential activity.

1. No extension of the Contract Time will be authorized because of failure to transmit submittals enough in advance of the Work to permit processing, including resubmittals.
2. Submit two copies of each action submittal. Design Team will return one copy.
3. Submit one copy of each informational submittal. Design Team will not return copies.
4. Design Team will discard submittals received from sources other than Contractor.

B. Electronic Submittals: Identify and incorporate information in each electronic submittal file as follows:

1. Assemble complete submittal package into a single indexed file incorporating submittal requirements of a single Specification Section and transmittal form with links enabling navigation to each item.
2. Name file with unique identifier, including project identifier, Specification Section number, and revision identifier.
3. Provide means for insertion to permanently record Contractor's review and approval markings and action taken by Design Team.

C. Identify options requiring selection by Design Team.

D. Identify deviations from the Contract Documents on submittals.

E. Contractor's Construction Schedule Submittal Procedure:

1. Submit required submittals in the following format:

   a. PDF electronic file.

2. Coordinate Contractor's construction schedule with the schedule of values, submittal schedule, progress reports, payment requests, and other required schedules and reports.

PART 2 - PRODUCTS

2.1 SUBMITTAL PROCEDURES

A. General Submittal Procedure Requirements: Prepare and submit submittals required by individual Specification Sections.

1. Submit electronic submittals via email as PDF electronic files to Shannon Hicks at GHR Engineers and Associates, Inc.: shicks@ghrinc.com.

   a. Design Team will return annotated file. Annotate and retain one copy of file as an electronic Project record document file.

2.2 ACTION SUBMITTALS

A. Submit two paper copies of each submittal unless otherwise indicated. Design Team will return one copy.

B. Product Data: Mark each copy to show applicable products and options. Include the following:

1. Manufacturer's written recommendations, product specifications, and installation instructions.
2. Wiring diagrams showing factory-installed wiring.
3. Printed performance curves and operational range diagrams.
4. Testing by recognized testing agency.
5. Compliance with specified standards and requirements.

C. Shop Drawings: Prepare Project-specific information, drawn accurately to scale. Do not base Shop Drawings on reproductions of the Contract Documents or standard printed data. Submit on sheets at least 8-1/2 by 11 inches but no larger than 30 by 42 inches. Include the following:

1. Dimensions and identification of products.
2. Fabrication and installation drawings and roughing-in and setting diagrams.
3. Wiring diagrams showing field-installed wiring.
4. Notation of coordination requirements.
5. Notation of dimensions established by field measurement.

2.3 INFORMATIONAL SUBMITTALS

A. Informational Submittals: Submit one paper copy of each submittal unless otherwise indicated. Design Team will not return copies.

B. Qualification Data: Include lists of completed projects with project names and addresses, names and addresses of Design Team and owners, and other information specified.

C. Product Certificates: Prepare written statements on manufacturer's letterhead certifying that product complies with requirements in the Contract Documents.

PART 3 - EXECUTION

3.1 SUBMITTAL REVIEW

A. Review each submittal and check for coordination with other Work of the Contract and for compliance with the Contract Documents. Note corrections and field dimensions. Mark with approval stamp before submitting to Design Team.

B. Design Team will review each action submittal, make marks to indicate corrections or modifications required, will stamp each submittal with an action stamp, and will mark stamp appropriately to indicate action.

C. Informational Submittals: Design Team will review each submittal and will not return it, or will return it if it does not comply with requirements. Design Team will forward each submittal to appropriate party.

D. Submittals not required by the Contract Documents may not be reviewed and may be discarded.

END OF SECTION 01 3000

SECTION 01 4000 - QUALITY REQUIREMENTS

PART 1 - GENERAL

1.1 SECTION REQUIREMENTS

A. Testing and inspecting services are required to verify compliance with requirements specified or indicated. These services do not relieve Contractor of responsibility for compliance with the Contract Document requirements.

B. Referenced Standards: If compliance with two or more standards is specified and the standards establish different or conflicting requirements, comply with the most stringent requirement. Refer uncertainties to Design Team for a decision.

C. Minimum Quantity or Quality Levels: The quantity or quality level shown or specified shall be the minimum. The actual installation may exceed the minimum within reasonable limits. Indicated numeric values are minimum or maximum, as appropriate, for the context of requirements. Refer uncertainties to Design Team for a decision.

D. Test and Inspection Reports: Prepare and submit certified written reports specified in other Sections. Include the following:

1. Date of issue.
2. Project title and number.
3. Name, address, and telephone number of testing agency.
4. Dates and locations of samples and tests or inspections.
5. Names of individuals making tests and inspections.
6. Description of the Work and test and inspection method.
7. Identification of product and Specification Section.
8. Complete test or inspection data.
9. Test and inspection results and an interpretation of test results.
10. Record of temperature and weather conditions at time of sample taking and testing and inspecting.
11. Comments or professional opinion on whether tested or inspected Work complies with the Contract Document requirements.
12. Name and signature of laboratory inspector.
13. Recommendations on retesting and reinspecting.

E. Permits, Licenses, and Certificates: For Owner's records, submit copies of permits, licenses, certifications, inspection reports, notices, receipts for fee payments, and similar documents, established for compliance with standards and regulations bearing on performance of the Work.

F. Testing Agency Qualifications: An independent agency with the experience and capability to conduct testing and inspecting indicated; and where required by authorities having jurisdiction, that is acceptable to authorities.

G. Retesting / Reinspecting: Regardless of whether original tests or inspections were Contractor's responsibility, provide quality-control services, including retesting and reinspecting, for construction that replaced work that failed to comply with the Contract Documents.

H. Testing Agency Responsibilities: Cooperate with Design Team and Contractor in performance of duties. Provide qualified personnel to perform required tests and inspections.

1. Notify Design Team and Contractor of irregularities or deficiencies in the work observed during performance of its services.
2. Do not release, revoke, alter or increase requirements of the Contract Documents or approve or accept any portion of the work.
3. Do not perform any duties of Contractor.

I. Coordination: Coordinate sequence of activities to accommodate required quality-assurance and -control services with a minimum of delay and to avoid necessity of removing and replacing construction to accommodate testing and inspecting.

1. Schedule times for tests, inspections, obtaining samples, and similar activities.

J. Tests and Inspections: Owner will engage a qualified inspector to conduct inspections required by authorities having jurisdiction.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 REPAIR AND PROTECTION

A. Repair and protection are Contractor's responsibility, regardless of the assignment of responsibility for quality-control services.

B. Contractor will maintain a safe work site at all times. When the project is complete, Contractor shall return the work site and the surrounding areas to the same condition as they were prior to the beginning of the project.

END OF SECTION 01 4000

SECTION 01 6000 - PRODUCT REQUIREMENTS

PART 1 - GENERAL

1.1 SECTION REQUIREMENTS

A. The term "product" includes the terms "material," "equipment," "system," and terms of similar intent.

B. Comparable Product Requests: Submit request for consideration of each comparable product. Identify product or fabrication or installation method to be replaced.

1. Show compliance with requirements for comparable product requests.
2. Design Team will review the proposed product and notify Contractor of its acceptance or rejection.

C. Basis-of-Design Product Specification Submittal: Show compliance with requirements.

D. Compatibility of Options: If Contractor is given option of selecting between two or more products, select product compatible with products previously selected.

E. Deliver, store, and handle products using means and methods that will prevent damage, deterioration, and loss, including theft. Comply with manufacturer's written instructions.

1. Schedule delivery to minimize long-term storage at Project site and to prevent overcrowding of construction spaces.
2. Deliver products to Project site in manufacturer's original sealed container or packaging, complete with labels and instructions for handling, storing, unpacking, protecting, and installing.
3. Inspect products on delivery to ensure compliance with the Contract Documents and to ensure that products are undamaged and properly protected.
4. Store materials in a manner that will not endanger Project structure.
5. Store products that are subject to damage by the elements, under cover in a weathertight enclosure above ground, with ventilation adequate to prevent condensation.

F. Warranties specified in other Sections shall be in addition to, and run concurrent with, other warranties required by the Contract Documents. Manufacturer's disclaimers and limitations on product warranties do not relieve Contractor of obligations under requirements of the Contract Documents.

PART 2 - PRODUCTS

2.1 PRODUCT SELECTION PROCEDURES

A. Provide products that comply with the Contract Documents, are undamaged, and, unless otherwise indicated, are new at the time of installation.

1. Provide products complete with accessories, trim, finish, and other devices and components needed for a complete installation and the intended use and effect.
2. Where products are accompanied by the term "as selected," Owner will make selection.
3. Descriptive, performance, and reference standard requirements in the Specifications establish salient characteristics of products.

B. Where the following headings are used to list products or manufacturers, the Contractor's options for product selection are as follows:

1. Products:

a. Where requirements include "one of the following," provide one of the products listed that complies with requirements.
b. Where requirements do not include "one of the following," provide one of the products listed that complies with requirements or a comparable product.

2. Manufacturers:

a. Where requirements include "one of the following," provide a product that complies with requirements by one of the listed manufacturers.
b. Where requirements do not include "one of the following," provide a product that complies with requirements by one of the listed manufacturers or another manufacturer.

3. Basis-of-Design Product: Provide the product named, or indicated on the Drawings, or a comparable product by one of the listed manufacturers.

2.2 COMPARABLE PRODUCTS

A. Design Team will consider Contractor's request for comparable product in advance of Bidding only when the following conditions are satisfied:

1. Evidence that the proposed product does not require revisions to the Contract Documents, that it is consistent with the Contract Documents and will produce the indicated results, and that it is compatible with other portions of the Work.
2. Detailed comparison of significant qualities of proposed product with those named in the Specifications.
3. List of similar installations for completed projects, if requested.
4. Samples, where applicable.

PART 3 - EXECUTION (Not Used)

END OF SECTION 01 6000

SECTION 01 7000 - EXECUTION AND CLOSEOUT REQUIREMENTS

PART 1 - GENERAL

1.1 EXECUTION REQUIREMENTS

A. Cutting and Patching:

1. Structural Elements: When cutting and patching structural elements, notify Design Team of locations and details of cutting and await directions from Architect before proceeding. Shore, brace, and support structural elements during cutting and patching.
2. Operational Elements: Do not cut and patch operating elements and related components in a manner that results in reducing their capacity to perform as intended or that results in increased maintenance or decreased operational life or safety.
3. Visual Elements: Do not cut and patch construction in a manner that results in visual evidence of cutting and patching. Do not cut and patch exposed construction in a manner that would, in Architect's opinion, reduce the building's aesthetic qualities.

B. Manufacturer's Installation Instructions: Obtain and maintain on-site manufacturer's written recommendations and instructions for installation of products and equipment.

1.2 CLOSEOUT SUBMITTALS

A. Contractor's List of Incomplete Items: Initial submittal at Substantial Completion.

B. Certified List of Incomplete Items: Final submittal at Final Completion.

C. Operation and Maintenance Data: Submit two (2) copies of manual.

D. PDF Electronic File: Assemble manual into a composite electronically indexed file. Submit two (2) copies on digital media.

E. Record Product Data: Submit two (2) paper copies and annotated PDF electronic files and directories of each submittal.

1.3 SUBSTANTIAL COMPLETION PROCEDURES

A. Prepare a list of items to be completed and corrected (punch list), the value of items on the list, and reasons why the Work is not complete.

B. Submittals Prior to Substantial Completion: Before requesting Substantial Completion inspection, complete the following:

1. Submit closeout submittals specified in other sections, including project record documents, operation and maintenance manuals, similar final record information, warranties, workmanship bonds, maintenance service agreements, final certifications, and similar documents.
2. Submit maintenance material submittals specified in other sections, including tools, spare parts, extra materials, and similar items, and deliver to location designated by Owner.
3. Submit test/adjust/balance records.

C. Procedures Prior to Substantial Completion: Before requesting Substantial Completion inspection, complete the following:

1. Complete startup and testing of systems and equipment.
2. Perform preventive maintenance on equipment used prior to Substantial Completion.
3. Remove temporary facilities and controls.
4. Complete final cleaning requirements, including touchup painting.
5. Touch up and otherwise repair and restore marred exposed finishes to eliminate visual defects.

D. Inspection: Submit a written request for inspection for Substantial Completion. On receipt of request, Architect will proceed with inspection or advise Contractor of unfulfilled requirements. Architect will prepare the Certificate of Substantial Completion after inspection or will advise Contractor of items that must be completed or corrected before certificate will be issued.

1.4 FINAL COMPLETION PROCEDURES

A. Submittals Prior to Final Completion: Before requesting inspection for determining final completion, complete the following:

1. Submit a final Application for Payment.

2. Submit certified copy of Architect's Substantial Completion inspection list of items to be completed or corrected (punch list), endorsed and dated by Architect. Certified copy of the list shall state that each item has been completed or otherwise resolved.

B. Submit a written request for final inspection for acceptance. On receipt of request, Design Team will either proceed with inspection or notify Contractor of unfulfilled requirements. Architect will prepare final Certificate for Payment after inspection or will advise Contractor of items that must be completed or corrected before certificate will be issued.

1. Reinspection: Request reinspection when the Work identified in previous inspections as incomplete is completed or corrected.

PART 2 - PRODUCTS

2.1 MATERIALS

A. In-Place Materials: Use materials for patching identical to in-place materials. For exposed surfaces, use materials that visually match in-place adjacent surfaces to the fullest extent possible.

B. Cleaning Agents: Use cleaning materials and agents recommended by manufacturer or fabricator of the surface to be cleaned. Do not use cleaning agents that are potentially hazardous to health or property or that might damage finished surfaces.

1. Use cleaning products that comply with Green Seal's GS-37, or if GS-37 is not applicable, use products that comply with the California Code of Regulations maximum allowable VOC levels.

2.2 OPERATION AND MAINTENANCE DOCUMENTATION

A. Directory: Prepare a single, comprehensive directory of operation and maintenance data and materials, listing items and their location to facilitate ready access to desired information.

B. Organization: Unless otherwise indicated, organize manual into separate sections for each system and subsystem, and separate sections for each piece of equipment not part of a system.

1. Dividers: Provide heavy paper dividers with celluloid-covered tabs for each separate Section. Mark each tab to indicate contents. Provide a typed description of the product and major parts of equipment included in the Section on each divider.

C. Organize data into three-ring binders with identification on front and spine of each binder, and envelopes for folded drawings. Identify each binder on the front and spine with the printed title "OPERATION AND MAINTENANCE MANUAL", Project title or name, year and subject matter covered. Indicate volume number for multiple volume sets of manuals. Include the following:

1. Manufacturer's operation and maintenance documentation.
2. Maintenance and service schedules.
3. Maintenance service contracts. Include name and telephone number of service agent.
4. Emergency instructions.
5. Spare parts list and local sources of maintenance materials.
6. Wiring diagrams.
7. Copies of warranties. Include procedures to follow and required notifications for warranty claims

2.3 RECORD DRAWINGS

A. Record Prints: Maintain a set of prints of the Contract Drawings and Shop Drawings, incorporating new and revised drawings as modifications are issued. Mark to show actual installation where installation varies from that shown originally. Accurately record information in an acceptable drawing technique.

1. Identify and date each record Drawing; include the designation "PROJECT RECORD DRAWING" in a prominent location.

B. Record Digital Data Files: Immediately before inspection for Certificate of Substantial Completion, review marked-up record prints with Architect. When authorized, prepare a full set of corrected digital data files of the Contract Drawings.

1. Format: Annotated PDF electronic file.

PART 3 - EXECUTION

3.1 EXAMINATION AND PREPARATION

A. Before proceeding with each component of the Work, examine substrates, areas, and conditions, with Installer or Applicator present where indicated, for compliance with requirements for installation tolerances and other conditions affecting performance.

1. Verify compatibility with and suitability of substrates.
2. Examine roughing-in for mechanical and electrical systems.
3. Examine walls, floors, and roofs for suitable conditions.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

C. Take field measurements as required to fit the Work properly. Where portions of the Work are indicated to fit to other construction, verify dimensions of other construction by field measurements before fabrication.

D. Verify space requirements and dimensions of items shown diagrammatically on Drawings.

3.2 CONSTRUCTION LAYOUT

A. Before proceeding to lay out the Work, verify layout information shown on Drawings.

3.3 INSTALLATION

A. Locate the Work and components of the Work accurately, in correct alignment and elevation, as indicated.

1. Make vertical work plumb and make horizontal work level.
2. Conceal wiring in finished areas unless otherwise indicated.
3. Maintain minimum headroom clearance of 96 inches in occupied spaces and 90 inches in unoccupied spaces.

B. Comply with manufacturer's written instructions and recommendations.

C. Conduct construction operations so no part of the Work is subjected to damaging operations or loading in excess of that expected during normal conditions of occupancy.

D. Templates: Obtain and distribute to the parties involved templates for work specified to be factory prepared and field installed.

E. Attachment: Provide blocking and attachment plates and anchors and fasteners of adequate size and number to securely anchor each component in place. Where size and type of attachments are not indicated, verify size and type required for load conditions.

1. Mounting Heights: Where mounting heights are not indicated, mount components at heights directed by Owner.

F. Joints: Make joints of uniform width. Where joint locations in exposed work are not indicated, arrange joints for the best visual effect. Fit exposed connections together to form hairline joints.

G. Use products, cleaners, and installation materials that are not considered hazardous.

3.4 CUTTING AND PATCHING

A. Provide temporary support of work to be cut.

B. Protection: Protect in-place construction during cutting and patching to prevent damage. Provide protection from adverse weather conditions for portions of Project that might be exposed during cutting and patching operations.

C. Where existing services/systems are required to be removed, relocated, or abandoned, bypass such services/systems before cutting to prevent interruption to occupied areas.

D. Cutting: Cut in-place construction using methods least likely to damage elements retained or adjoining construction.

1. Cut holes and slots neatly to minimum size required, and with minimum disturbance of adjacent surfaces. Temporarily cover openings when not in use.

E. Patch with durable seams that are as invisible as possible. Provide materials and comply with installation requirements specified in other Sections.

1. Restore exposed finishes of patched areas and extend finish restoration into adjoining construction in a manner that will minimize evidence of patching and refinishing.

2. Where walls or partitions that are removed extend one finished area into another, patch and repair floor and wall surfaces in the new space. Provide an even surface of uniform finish, color, texture, and appearance.
3. Where patching occurs in a painted surface, prepare substrate and apply primer and intermediate paint coats appropriate for substrate over the patch, and apply final paint coat over entire unbroken surface containing the patch. Provide additional coats until patch blends with adjacent surfaces.

3.5 CLEANING

A. Clean Project site and work areas daily, including common areas. Dispose of materials lawfully.

1. Remove liquid spills promptly.
2. Where dust would impair proper execution of the Work, broom-clean or vacuum the entire work area, as appropriate.
3. Remove debris from concealed spaces before enclosing the space.

B. Complete the following cleaning operations before requesting inspection for certification of Substantial Completion:

1. Clean Project site and grounds, in areas disturbed by construction activities. Sweep paved areas; remove stains, spills, and foreign deposits. Rake grounds that are neither planted nor paved to a smooth, even-textured surface.
2. Sweep paved areas broom clean. Remove spills, stains, and other foreign deposits.
3. Remove labels that are not permanent.
4. Clean transparent materials, including mirrors. Remove excess glazing compounds.
5. Clean exposed finishes to a dust-free condition, free of stains, films, and foreign substances. Sweep concrete floors broom clean.
6. Vacuum carpeted surfaces.
7. Wipe surfaces of mechanical and electrical equipment. Remove excess lubrication and foreign substances. Clean plumbing fixtures. Clean light fixtures, lamps, globes, and reflectors.

3.6 OPERATION AND MAINTENANCE MANUAL PREPARATION

A. Operation and Maintenance Manuals: Assemble a complete set of operation and maintenance data indicating operation and maintenance of each system, subsystem, and piece of equipment not part of a system.

B. Manufacturers' Data: Where manuals contain manufacturers' standard printed data, include only sheets pertinent to product or component installed. Mark each sheet to identify each product or component incorporated into the Work. If data include more than one item in a tabular format, identify each item using appropriate references from the Contract Documents. Identify data applicable to the Work and delete references to information not applicable.

1. Prepare supplementary text if manufacturers' standard printed data are unavailable and where the information is necessary for proper operation and maintenance of equipment or systems.

C. Drawings: Prepare drawings supplementing manufacturers' printed data to illustrate the relationship of component parts of equipment and systems and to illustrate control sequence and flow diagrams.

3.7 DEMONSTRATION AND TRAINING

A. Contractor to instruct Owner's personnel to adjust, operate, and maintain systems, subsystems, and equipment not part of a system. Include a detailed review of the following:

1. Include instruction for basis of system design and operational requirements, review of documentation, emergency procedures, operations, adjustments, troubleshooting, maintenance, and repairs.

B. Contractor shall train Owner’s teaching faculty on the online monitoring functionality of new system.

END OF SECTION 01 7000

SECTION 01 7419 - CONSTRUCTION WASTE MANAGEMENT AND DISPOSAL

PART 1 - GENERAL (Not Used)

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 PLAN IMPLEMENTATION

A. General: Provide handling, containers, storage, signage, transportation, and other items as required to implement waste management plan during the entire duration of the Contract.

B. Training: Train workers, subcontractors, and suppliers on proper waste management procedures, as appropriate for the Work occurring at Project site.

1. Review locations established for recycling and disposal.

3.2 RECYCLING WASTE

A. Packaging:

1. Cardboard and Boxes: Break down packaging into flat sheets. Bundle and store in a dry location.
2. Polystyrene Packaging: Separate and bag materials.
3. Pallets: As much as possible, require deliveries using pallets to remove pallets from Project site. For pallets that remain on-site, break down pallets into component wood pieces and comply with requirements for recycling wood.
4. Crates: Break down crates into component wood pieces and comply with requirements for recycling wood.

B. Wood Materials:

1. Sort and stack reusable members according to size, type, and length. Separate lumber, engineered wood products, panel products, and treated wood materials.
2. Clean Cut-Offs of Lumber: Grind or chip into small pieces.
3. Clean Sawdust: Bag sawdust that does not contain painted or treated wood.

C. Metals: Separate metals by type.

3.3 DISPOSAL OF WASTE

A. Except for items or materials to be recycled or otherwise reused, remove waste materials from Project site and legally dispose of them in a landfill or incinerator acceptable to authorities having jurisdiction.

B. Recycle recyclable materials off-site.

C. Do not burn waste materials.

END OF SECTION 01 7419

SECTION 230513 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

Revise this Section by deleting and inserting text to meet Project-specific requirements.

See "Legislation and Energy Efficiency" Article in the Evaluations for information about the 2016 DOE ruling for motors.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on alternating-current power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

1.3 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:

1. Motor controllers.
2. Torque, speed, and horsepower requirements of the load.
3. Ratings and characteristics of supply circuit and required control sequence.
4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Comply with NEMA MG 1 unless otherwise indicated.

Retain paragraph below if severe-duty motors are required.

B. Comply with IEEE 841 for severe-duty motors.

2.2 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet (1000 m) above sea level.

B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

2.3 POLYPHASE MOTORS

This Section is written around Design B motors. For Design A or Design C, edit below and revise other characteristics accordingly (note that Design A and Design C motors still must meet NEMA Premium efficiency levels). According to the DOE, NEMA MG 1, Design B motors are the most common motors used in equipment in the United States, accounting for 96.13 percent of all motor shipments in 2011.

A. Description: NEMA MG 1, Design B, medium induction motor.

See "Energy Considerations" Article in the Evaluations for discussion of motor efficiency.

B. Efficiency: Premium efficient, as defined in NEMA MG 1.

Retain "Service Factor" Paragraph below for service factors exceeding NEMA standard for other than open-dripproof motors. If retaining, coordinate with Drawings or other Sections specifying motorized equipment. See "Product Characteristics" Article in the Evaluations for discussion of service factor. A service factor of at least 1.15 is available for most motors, including explosion proof; however, there are exceptions.

C. Service Factor: 1.15.

Retain one of two "Multispeed Motors" paragraphs below. Retain first paragraph for lower first cost. Retain second to require all multispeed motors to be two-winding type. See "Multispeed and Variable-Speed Considerations" Article in the Evaluations.

D. Multispeed Motors: Variable torque.

1. For motors with 2:1 speed ratio, consequent pole, single winding.
2. For motors with other than 2:1 speed ratio, separate winding for each speed.

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

NEMA MG 1 recommends ball bearings for polyphase motors 500 hp and smaller due to their ability to sustain coupling end-play and rotor float. Some smaller integral and fractional polyphase motors might have sleeve bearings for lower cost and quieter operation, especially if direct coupled and not subjected to belted loads. For motor-bearing requirements for specific equipment, specify those requirements in motorized equipment Sections. Coordinate with equipment suppliers for bearing types in smaller motors. Specify bearing-life requirements, according to ABMA 9, in motor-driven equipment Sections.

G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.

For longer motor insulation life, consider specifying a temperature rise one class below the insulation rating class; for example, Class F insulation with Class B temperature rise. Many energy-efficient and most premium-efficient motors come standard with Class F insulation and Class B temperature rise to obtain higher service factors and meet energy-efficiency levels.

H. Temperature Rise: Match insulation rating.

Standard insulation class for general-purpose, open-dripproof motors, of nominal efficiency rating, is Class B; however, many premium-efficient motors, and those with service factors 1.15 or higher, are built with insulation meeting Class F requirements, especially if designed as "inverter ready" for use with variable-frequency controllers. Retain option in "Insulation" Paragraph below unless a higher or lower insulation class is required as a default.

I. Insulation: [**Class F**] <**Insert class**>.

J. Code Letter Designation:

Starting codes in first subparagraph below are adequate for most variable-torque loads encountered in HVAC applications; 15 hp is a common breakpoint in rating among manufacturers when Code F and Code G apply. Retain both subparagraphs and options unless Project conditions or equipment characteristics otherwise dictate.

1. Motors [**15**] <**Insert number**> HP and Larger: NEMA starting Code F or Code G.
2. Motors Smaller Than [**15**] <**Insert number**> HP: Manufacturer's standard starting characteristic.

See "Product Characteristics" Article in the Evaluations for enclosure frame material discussion. Retain "Enclosure Material" Paragraph below to require other than manufacturer's standard enclosure materials. Specify other types of enclosures in motorized-equipment Sections.

K. Enclosure Material: Cast iron for motor frame sizes [**324T**] <**Insert number**> and larger; rolled steel for motor frame sizes smaller than [**324T**] <**Insert number**>.

2.4 ADDITIONAL REQUIREMENTS FOR POLYPHASE MOTORS

See "Multispeed and Variable-Speed Considerations" Article in the Evaluations for discussion of motor controllers. Retain "Motors Used with Reduced-Voltage and Multispeed Controllers" Paragraph below only if Project includes separately connected motors and where controllers are not furnished as a component of the motorized equipment.

A. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

See "Multispeed and Variable-Speed Considerations" Article in the Evaluations for discussion of motor types used with variable-frequency controllers. Retain option in "Motors Used with Variable-Frequency Controllers" Paragraph below if Project includes separately connected motors.

B. Motors Used with Variable-Frequency Controllers:[**Ratings, characteristics, and features coordinated with and approved by controller manufacturer.**]

1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width-modulated inverters.
2. Premium-Efficient Motors: Class B temperature rise; Class F insulation.
3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.

See "Multispeed and Variable-Speed Considerations" Article in the Evaluations for discussion of thermally protected motors. Thermal protection is not usually required for HVAC equipment and energy- or premium-efficient motors specified in this Section. Retain "Thermal Protection" Subparagraph below to require added protection from overheating or if inverter-duty motors are required.

4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

Retain paragraph below only if Project requires severe-duty motors, based on environmental conditions.

C. Severe-Duty Motors: Comply with IEEE 841, with 1.15 minimum service factor.

2.5 SINGLE-PHASE MOTORS

A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:

See the Evaluations for a comparison of single-phase motor types.

1. Permanent-split capacitor.
2. Split phase.
3. Capacitor start, inductor run.
4. Capacitor start, capacitor run.

B. Multispeed Motors: Variable-torque, permanent-split-capacitor type.

C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.

D. Motors 1/20 HP and Smaller: Shaded-pole type.

E. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230513

SECTION 230517 - SLEEVES AND SLEEVE SEALS FOR HVAC PIPING

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on Masterworks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on Masterworks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Sleeves.
2. Stack-sleeve fittings.
3. Sleeve-seal systems.
4. Sleeve-seal fittings.
5. Grout.
6. Silicone sealants.

B. Related Requirements:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 078413 "Penetration Firestopping" for penetration firestopping installed in fire-resistance-rated walls, horizontal assemblies, and smoke barriers, with and without penetrating items.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for sealants.>

1.4 INFORMATIONAL SUBMITTALS

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

A. Field quality-control reports.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and Masterworks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 SLEEVES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Advance Products & Systems, Inc.
2. CALPICO, Inc.

B. Cast-Iron Pipe Sleeves: Cast or fabricated of cast or ductile iron and equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop collar.

C. Steel Pipe Sleeves: ASTM A53/A53M, Type E, Grade B, Schedule 40, [**anti-corrosion coated**] [**or**] [**zinc coated**], with plain ends and integral welded waterstop collar.

D. Galvanized-Steel Sheet Sleeves: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.

PVC sleeves in "PVC Pipe Sleeves" and "Molded-PVC Sleeves" paragraphs below may be prohibited by authorities having jurisdiction.

E. PVC Pipe Sleeves: ASTM D1785, Schedule 40.

F. Molded-PVC Sleeves: With nailing flange for attaching to wooden forms.

G. Molded-PE or -PP Sleeves: Removable, tapered-cup shaped, and smooth outer surface with nailing flange for attaching to wooden forms.

2.2 STACK-SLEEVE FITTINGS

Stack-sleeve fittings are used as a watertight sleeve for piping passing through concrete floors and roofs. Grout is used to seal the annular space between fitting and slab opening. Silicone sealant is used to seal annular space between the pipe and top hub of fitting.

A. Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Jay R. Smith Mfg Co; a division of Morris Group International.

Natural cast iron is subject to surface discoloration caused by oxidation. If this is a concern, consider retaining one of the options in the "Description" Paragraph below.

B. Description: Manufactured, [**Dura-coated or Duco-coated**] [**galvanized**] cast-iron sleeve with integral cast flashing flange for use in waterproof floors and roofs. Include clamping ring, bolts, and nuts for membrane flashing.

Retain "Underdeck Clamp" Subparagraph below if required for securing fitting to slab.

1. Underdeck Clamp: Clamping ring with setscrews.

2.3 SLEEVE-SEAL SYSTEMS

Sleeve-seal systems in this article are used for piping penetrations in slabs-on-grade and below grade in exterior walls.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Advance Products & Systems, Inc.
2. Airex Manufacturing.
3. CALPICO, Inc.
4. GPT; an EnPro Industries company.
5. Metraflex Company (The).

B. Description:

1. Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.
2. Designed to form a hydrostatic seal of 20-psig.

In "Sealing Elements" Subparagraph below, retain first option for standard applications with temperature ranges from minus 40 deg F (minus 40 deg C)to 250 deg F (121 deg C). Retain second option for wide- and high-temperature-range applications fromminus 67 deg F (minus 55 deg C) to)400 deg F (204 deg C).Retain third option if hydrocarbons are present in the soil. Coordinate with application recommendations of retained manufacturers.

3. Sealing Elements: [**EPDM-rubber**] [**High-temperature-silicone**] [**Nitrile (Buna N)**] interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size.

In "Pressure Plates" Subparagraph below, retain first or second option for standard applications. Retain third or fourth option when hydrocarbons are present in soil. Coordinate with application recommendations of retained manufacturers.

4. Pressure Plates: [**Carbon steel**] [**Composite plastic**] [**Stainless steel**] [**Stainless steel, Type 316**].

In "Connecting Bolts and Nuts" Subparagraph below, retain first option for standard applications. Retain second or third option when hydrocarbons are present in soil or for wide- and high-temperature-range applications of minus 67 deg F (minus 55 deg C) to 400 deg F (204 deg C). Coordinate with application recommendations of retained manufacturers.

5. Connecting Bolts and Nuts: [**Carbon steel, with corrosion-resistant coating, ASTM B633**] [**Stainless steel**] [**Stainless steel, Type 316,**] of length required to secure pressure plates to sealing elements.

2.4 SLEEVE-SEAL FITTINGS

Sleeve-seal fittings in this article are used for piping penetrations in slabs-on-grade and in exterior walls. These fittings are made to match piping OD, so they must be selected to match penetrating piping size.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Advance Products & Systems, Inc.
2. CALPICO, Inc.
3. GPT; an EnPro Industries company.
4. Metraflex Company (The).

B. Description:

1. Manufactured plastic, sleeve-type, waterstop assembly, made for imbedding in concrete slab or wall.
2. Plastic or rubber waterstop collar with center opening to match piping OD.

2.5 GROUT

A. Description: Nonshrink, recommended for interior and exterior sealing openings in nonfire-rated walls or floors.

B. Standard: ASTM C1107/C1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.

C. Design Mix: 5000-psi, 28-day compressive strength.

D. Packaging: Premixed and factory packaged.

Retain "Silicone Sealants" Article when use of silicone sealants and silicone foams is permitted as an alternative to grout, for sealing of annular space between sleeve and wall or floor. Also, retain "Silicone Sealants" Article when retaining "Stack-Sleeve Fittings" Article, for sealing of annular space between pipe and top hub of fitting.

2.6 SILICONE SEALANTS

A. Silicone, S, NS, 25, NT: Single-component, nonsag, plus 25 percent and minus 25 percent movement capability, nontraffic-use, neutral-curing silicone joint sealant, ASTM C920, Type S, Grade NS, Class 25, use NT.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. GE Construction Sealants; Momentive Performance Materials Inc.
    b. Pecora Corporation.
    c. Permathane®/Acryl-R®; ITW Polymers Sealants North America.
    d. Polymeric Systems, Inc.
    e. Sherwin-Williams Company (The).

2. <Double click to insert sustainable design text for sealants.>
3. <Double click to insert sustainable design text for sealants.>

B. Silicone, S, P, 25, T, NT: Single-component, pourable, plus 25 percent and minus 25 percent movement capability, traffic- and nontraffic-use, neutral-curing silicone joint sealant; ASTM C920, Type S, Grade P, Class 25, Uses T and NT. Grade P Pourable (self-leveling) formulation is for opening in floors and other horizontal surfaces that are not fire rated.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. <**Insert manufacturer's name**>.

2. <Double click to insert sustainable design text for sealants.>
3. <Double click to insert sustainable design text for sealants.>

C. Silicone Foam: Multicomponent, silicone-based liquid elastomers that, when mixed, expand and cure in place to produce a flexible, nonshrinking foam.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. <**Insert manufacturer's name**>.

2. <Double click to insert sustainable design text for sealants.>
3. <Double click to insert sustainable design text for sealants.>

PART 3 - EXECUTION

See "Writing Guide" Article in the Evaluations for a discussion of how this Section is organized and the most efficient way to revise this Section.

3.1 SLEEVE INSTALLATION

A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls.

B. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide [**1-inch**] <**Insert dimension**> annular clear space between piping and concrete slabs and walls.

Retain subparagraph below if applicable.

1. Sleeves are not required for core-drilled holes.

C. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.

1. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.
2. Cut sleeves to length for mounting flush with both surfaces.

    a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas [**2 inches**] <**Insert dimension**> above finished floor level.

3. Using [**grout**] [**or**] [**silicone sealant**], seal space outside of sleeves in slabs and walls without sleeve-seal system.

D. Install sleeves for pipes passing through interior partitions.

1. Cut sleeves to length for mounting flush with both surfaces.

Revise subparagraph below as required for seismic design conditions. Coordinate sleeve requirements with Section 230719 "HVAC Piping Insulation."

2. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
3. Seal annular space between sleeve and piping or piping insulation; use sealants appropriate for size, depth, and location of joint.

Revise "Fire-Resistance-Rated Penetrations, Horizontal Assembly Penetrations, and Smoke-Barrier Penetrations" Paragraph below to suit Project.

E. Fire-Resistance-Rated Penetrations, Horizontal Assembly Penetrations, and Smoke-Barrier Penetrations: Maintain indicated fire or smoke rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with fire- and smoke-stop materials. Comply with requirements for firestopping and fill materials specified in Section 078413 "Penetration Firestopping."

3.2 STACK-SLEEVE-FITTING INSTALLATION

A. Install stack-sleeve fittings in new slabs as slabs are constructed.

Revise first subparagraph below as required for seismic design conditions. Coordinate stack-sleeve-fitting requirements with Section 230719 "HVAC Piping Insulation."

1. Install fittings that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
2. Secure flashing between clamping flanges for pipes penetrating floors with membrane waterproofing. Comply with requirements for flashing specified in Section 076200 "Sheet Metal Flashing and Trim."
3. Install section of cast-iron soil pipe to extend sleeve to 3 inches above finished floor level.
4. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
5. Using waterproof silicone sealant, seal space between top hub of stack-sleeve fitting and pipe.

Revise "Fire-Resistance-Rated, Horizontal Assembly, and Smoke Barrier Penetrations" Paragraph below to suit Project.

B. Fire-Resistance-Rated, Horizontal Assembly, and Smoke Barrier Penetrations: Maintain indicated fire or smoke rating of floors at pipe penetrations. Seal pipe penetrations with fire- and smoke-stop materials. Comply with requirements for firestopping specified in Section 078413 "Penetration Firestopping."

3.3 SLEEVE-SEAL-SYSTEM INSTALLATION

Sleeve-seal systems in this article are used in slabs-on-grade and below grade in exterior concrete walls, for a watertight seal around service piping entries into building. These systems typically require installation in a sleeve for proper operation.

A. Install sleeve-seal systems in sleeves in exterior concrete walls and slabs-on-grade at service piping entries into building.

B. Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in center of sleeve. Center piping in penetration, assemble sleeve-seal-system components, and install in annular space between piping and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make a watertight seal.

3.4 SLEEVE-SEAL-FITTING INSTALLATION

Sleeve-seal fittings in this article are used above and below grade in concrete slabs and in concrete walls, for a watertight seal around piping. These fittings do not require a sleeve.

A. Install sleeve-seal fittings as new walls and slabs are constructed.

B. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.

C. Secure nailing flanges to concrete forms.

D. Using [**grout**] [**or**] [**silicone sealant**], seal space around outside of sleeve-seal fittings.

3.5 FIELD QUALITY CONTROL

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

A. Perform the following tests and inspections:

1. Leak Test: After allowing for a full cure, test sleeves and sleeve seals for leaks. Repair leaks and retest until no leaks exist.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

B. Sleeves and sleeve seals will be considered defective if they do not pass tests and inspections.

3.6 SLEEVE AND SLEEVE-SEAL SCHEDULE

A. Use sleeves and sleeve seals for the following piping-penetration applications:

1. Exterior Concrete Walls Above Grade:

a. Piping Smaller Than [**NPS 6**] <**Insert pipe size**>: [**Cast-iron sleeves**] [**Steel pipe sleeves**] [**Sleeve-seal fittings**] <**Insert material**>.
b. Piping [**NPS 6**] <**Insert pipe size**> and Larger: [**Cast-iron pipe sleeves**] [**Steel pipe sleeves**] [**Sleeve-seal fittings**] <**Insert material**>.

2. Exterior Concrete Walls Below Grade:

a. Piping Smaller Than [**NPS 6**] <**Insert pipe size**>: [**Cast-iron pipe sleeves with sleeve-seal system**] [**Steel pipe sleeves with sleeve-seal system**] [**Sleeve-seal fittings**] <**Insert material**>.

Retain first subparagraph below if using sleeve-seal systems; delete if using sleeve-seal fittings.

1) Select sleeve size to allow for 1-inch <**Insert dimension**> annular clear space between piping and sleeve for installing sleeve-seal system.

b. Piping [**NPS 6**] <**Insert pipe size**> and Larger: [**Cast-iron pipe sleeves with sleeve-seal system**] [**Steel pipe sleeves with sleeve-seal system**] [**Sleeve-seal fittings**] <**Insert material**>.

Retain first subparagraph below if using sleeve-seal systems; delete if using sleeve-seal fittings.

1) Select sleeve size to allow for 1-inch <**Insert dimension**> annular clear space between piping and sleeve for installing sleeve-seal system.

3. Concrete Slabs-on-Grade:

a. Piping Smaller Than [**NPS 6**] <**Insert pipe size**>: [**Cast-iron pipe sleeves with sleeve-seal system**] [**Steel pipe sleeves with sleeve-seal system**] [**Sleeve-seal fittings**] <**Insert material**>.

Retain first subparagraph below if using sleeve-seal systems; delete if using sleeve-seal fittings.

1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

b. Piping [**NPS 6**] <**Insert pipe size**> and Larger: [**Cast-iron pipe sleeves with sleeve-seal system**] [**Steel pipe sleeves with sleeve-seal system**] [**Sleeve-seal fittings**] <**Insert material**>.

Retain first subparagraph below if using sleeve-seal systems; delete if using only galvanized-steel pipe sleeves.

1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

4. Concrete Slabs Above Grade:

a. Piping Smaller Than [**NPS 6**] <**Insert pipe size**>: [**Steel pipe sleeves**] [**PVC-pipe sleeves**] [**Stack-sleeve fittings**] [**Sleeve-seal fittings**] [**Molded-PE or -PP sleeves**] [**Molded-PVC sleeves**] <**Insert material**>.
b. Piping [**NPS 6**] <**Insert pipe size**> and Larger: [**Steel pipe sleeves**] [**PVC-pipe sleeves**] [**Stack-sleeve fittings**] <**Insert material**>.

5. Interior Partitions:

Verify, with fire authorities having jurisdiction, that PVC materials are allowed for sleeves.

a. Piping Smaller Than [**NPS 6**] <**Insert pipe size**>: [**Steel pipe sleeves**] [**PVC-pipe sleeves**] <**Insert material**>.
b. Piping [**NPS 6**] <**Insert pipe size**> and Larger: [**Galvanized-steel sheet sleeves**] <**Insert material**>.

END OF SECTION 230517

SECTION 230518 - ESCUTCHEONS FOR HVAC PIPING

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Escutcheons.
2. Floor plates.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. Existing Piping to Remain: Existing piping that is not to be removed and that is not otherwise indicated to be removed, removed and salvaged, or removed and reinstalled.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. BrassCraft Manufacturing Co.; a Masco company.
2. Dearborn Brass.
3. Jones Stephens Corp.
4. Keeney Manufacturing Company (The).
5. Mid-America Fittings, Inc.

2.2 ESCUTCHEONS

Retain types and finish options below that match those retained in Part 3.

Escutcheons described in "One-Piece, Steel Type"; "One-Piece, Stainless-Steel Type"; and "One-Piece, Cast-Brass Type" paragraphs below are generally available in 5/8-inch (15-mm) OD, 7/8-inch (22-mm) OD, 1-1/4-inch (32-mm) OD, 1-1/2-inch (38-mm) OD, 3/8-inch (10-mm) IPS, 1/2-inch (13-mm) IPS, 3/4-inch (19-mm) IPS, 1-1/4-inch (32-mm) IPS, 1-1/2-inch (38-mm) IPS, and 2-inch (50-mm) IPS. Stainless-steel escutcheons and brass escutcheons have limited size availability and are not offered by all manufacturers. Each finish is not offered with each base metal by all manufacturers. Consult manufacturers.

A. One-Piece, Steel Type: With [**polished, chrome-plated**] [**polished brass**] finish and setscrew fastener.

B. One-Piece, Stainless-Steel Type: With polished stainless-steel finish.

C. One-Piece, Cast-Brass Type: With [**polished, chrome-plated**] [**polished brass**] finish and setscrew fastener.

Escutcheons described in "One-Piece, Deep-Pattern Type" Paragraph below are generally available in 1-1/4-inch (32-mm) OD, 1-1/2-inch (38-mm) OD, 1-1/4-inch (32-mm) IPS, and 1-1/2-inch (38-mm) IPS. The "brass" option below has limited size availability and is not offered by every manufacturer. Consult manufacturers.

D. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped [**steel**] [**brass**] with polished, chrome-plated finish and spring-clip fasteners.

Escutcheons described in "One-Piece, Stamped-Steel Type" Paragraph below are generally available in 5/8-inch (15-mm) OD, 7/8-inch (22-mm) OD, 1-1/4-inch (32-mm) OD, 1-1/2-inch (38-mm) OD, 3/8-inch (10-mm) IPS, 1/2-inch (13-mm) IPS, 3/4-inch (19-mm) IPS, 1-inch (25-mm) IPS, 1-1/4-inch (32-mm) IPS, 1-1/2-inch (38-mm) IPS, and 2-inch (50-mm) IPS.

E. One-Piece, Stamped-Steel Type: With polished, chrome-plated finish and spring-clip fasteners.

Retain one or both finish options in "Split-Plate, Stamped-Steel Type" Paragraph below that match escutcheon types retained in Part 3. Escutcheons described in paragraph are generally available in 5/8-inch (15-mm) OD, 7/8-inch (22-mm) OD, 1-1/4-inch (32-mm) OD, 1-1/2-inch (38-mm) OD, 3/8-inch (10-mm) IPS, 1/2-inch (13-mm) IPS, 3/4-inch (19-mm) IPS, 1-inch (25-mm) IPS, 1-1/4-inch (32-mm) IPS, 1-1/2-inch (38-mm) IPS, and 2-inch (50-mm) IPS.

F. Split-Plate, Stamped-Steel Type: With polished, chrome-plated finish; [**concealed**] [**and**] [**exposed-rivet**] hinge; and spring-clip fasteners.

2.3 FLOOR PLATES

Escutcheons described in "Split Floor Plates" Paragraph below are generally available in 5/8-inch (15-mm) OD, 7/8-inch (22-mm) OD, 1-1/4-inch (32-mm) OD, 1-1/2-inch (38-mm) OD, 3/8-inch (10-mm) IPS, 1/2-inch (13-mm) IPS, 3/4-inch (19-mm) IPS, 1-1/4-inch (32-mm) IPS, 1-1/2-inch (38-mm) IPS, and 2-inch (50-mm) IPS. Consult manufacturers.

A. Split Floor Plates: Steel with concealed hinge.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install escutcheons for piping penetrations of walls, ceilings, and finished floors.

B. Install escutcheons with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.

Coordinate retained selections with Section 210518 "Escutcheons for Fire-Suppression Piping" and Section 220518 "Escutcheons for Plumbing Piping" for consistency.

See Part 2 for information on availability of finishes and sizes.

1. Escutcheons for New Piping[**and Relocated Existing Piping**]:

   a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep pattern.
   b. Chrome-Plated Piping: One-piece [**steel**] [**cast brass**][**or split-plate steel**] with polished, chrome-plated finish.

Retain one of four "Insulated Piping" subparagraphs below.

   c. Insulated Piping: One-piece steel with [**polished, chrome-plated**] [**polished brass**] finish.
   d. Insulated Piping: One-piece stainless steel with polished stainless-steel finish.

e. Insulated Piping: One-piece cast brass with [**polished, chrome-plated**] [**polished brass**] finish.

f. Insulated Piping: One-piece stamped steel [**or split-plate, stamped steel with concealed hinge**] [**or split-plate, stamped steel with exposed-rivet hinge**] with polished, chrome-plated finish.

Retain one of four "Bare Piping at Wall and Floor Penetrations in Finished Spaces" subparagraphs below.

g. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece steel with [**polished, chrome-plated**] [**polished brass**] finish.

h. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece stainless steel with polished stainless-steel finish.

i. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece cast brass with [**polished, chrome-plated**] [**polished brass**] finish.

j. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece stamped steel [**or split-plate, stamped steel with concealed hinge**] [**or split-plate, stamped steel with exposed-rivet hinge**] with polished, chrome-plated finish.

Retain one of four "Bare Piping at Ceiling Penetrations in Finished Spaces" subparagraphs below.

k. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece steel with [**polished, chrome-plated**] [**polished brass**] finish.

l. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece stainless steel with polished stainless-steel finish.

m. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece cast brass with [**polished, chrome-plated**] [**polished brass**] finish.

n. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece stamped steel [**or split-plate, stamped steel with concealed hinge**] [**or split-plate, stamped steel with exposed-rivet hinge**] with polished, chrome-plated finish.

Retain one of three "Bare Piping in Unfinished Service Spaces" subparagraphs below.

o. Bare Piping in Unfinished Service Spaces: One-piece steel with polished, chrome-plated finish.

p. Bare Piping in Unfinished Service Spaces: One-piece cast brass with [**polished, chrome-plated**] [**rough-brass**] finish.

q. Bare Piping in Unfinished Service Spaces: One-piece stamped steel [**or split-plate, stamped steel with concealed hinge**] [**or split-plate, stamped steel with exposed-rivet hinge**] with polished, chrome-plated finish.

Retain one of three "Bare Piping in Equipment Rooms" subparagraphs below.

r. Bare Piping in Equipment Rooms: One-piece steel with polished, chrome-plated finish.

s. Bare Piping in Equipment Rooms: One-piece cast brass with [**polished, chrome-plated**] [**rough-brass**] finish.

t. Bare Piping in Equipment Rooms: One-piece stamped steel [**or split-plate, stamped steel with concealed hinge**] [**or split-plate, stamped steel with exposed-rivet hinge**] with polished, chrome-plated finish.

2. Escutcheons for Existing Piping to Remain:

a. Chrome-Plated Piping: Split-plate, stamped steel with [**concealed**] [**or**] [**exposed-rivet**] hinge with polished, chrome-plated finish.

b. Insulated Piping: Split-plate, stamped steel with [**concealed**] [**or**] [**exposed-rivet**] hinge with polished, chrome-plated finish.
c. Bare Piping at Wall and Floor Penetrations in Finished Spaces: Split-plate, stamped steel with [**concealed**] [**or**] [**exposed-rivet**] hinge with polished, chrome-plated finish.
d. Bare Piping at Ceiling Penetrations in Finished Spaces: Split-plate, stamped steel with [**concealed**] [**or**] [**exposed-rivet**] hinge with polished, chrome-plated finish.
e. Bare Piping in Unfinished Service Spaces: Split-plate, stamped steel with [**concealed**] [**or**] [**exposed-rivet**] hinge with polished, chrome-plated finish.
f. Bare Piping in Equipment Rooms: Split-plate, stamped steel with [**concealed**] [**or**] [**exposed-rivet**] hinge with polished, chrome-plated finish.

C. Install floor plates for piping penetrations of equipment-room floors.

D. Install floor plates with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.

Subparagraphs below apply to both bare and insulated piping.

1. New Piping [**and**] [**Relocated Existing Piping**]: Split floor plate.
2. Existing Piping to Remain: Split floor plate.

3.2 FIELD QUALITY CONTROL

A. Using new materials, replace broken and damaged escutcheons and floor plates.

END OF SECTION 230518

SECTION 230548 - VIBRATION AND SEISMIC CONTROLS FOR HVAC

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Use this Section if Project is in a seismic area. Use Section 230548.13 "Vibration Controls for HVAC" for Projects not in a seismic area.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Elastomeric isolation pads.
2. Elastomeric isolation mounts.
3. Restrained elastomeric isolation mounts.
4. Open-spring isolators.
5. Housed-spring isolators.
6. Restrained-spring isolators.
7. Housed-restrained-spring isolators.
8. Pipe-riser resilient supports.
9. Resilient pipe guides.
10. Air-spring isolators.
11. Restrained-air-spring isolators.
12. Elastomeric hangers.
13. Spring hangers.
14. Snubbers.
15. Restraint channel bracings.
16. Restraint cables.
17. Seismic-restraint accessories.
18. Mechanical anchor bolts.
19. Adhesive anchor bolts.
20. Vibration isolation equipment bases.
21. Restrained isolation roof-curb rails.

B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 210548 "Vibration and Seismic Controls for Fire Suppression" for devices for fire-suppression equipment and systems.
2. Section 220548 "Vibration and Seismic Controls for Plumbing" for devices for plumbing equipment and systems.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. IBC: International Building Code.

B. ICC-ES: ICC-Evaluation Service.

C. OSHPD: Office of Statewide Health Planning & Development (for the State of California).

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.

2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of vibration isolation device and seismic-restraint component required.

See Evaluations for a discussion on seismic-restraint capacities and rating services.

a. Tabulate types and sizes of seismic restraints, complete with report numbers and rated strength in tension and shear as evaluated by [**an evaluation service member of ICC-ES**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**].
b. Annotate to indicate application of each product submitted and compliance with requirements.

3. Interlocking Snubbers: Include ratings for horizontal, vertical, and combined loads.

B. Shop Drawings:

1. Detail fabrication and assembly of equipment bases. Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

C. Delegated-Design Submittal: For each vibration isolation and seismic-restraint device.

1. Include design calculations and details for selecting vibration isolators, seismic restraints, and vibration isolation bases complying with performance requirements, design criteria, and analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
2. Design Calculations: Calculate static and dynamic loading due to equipment weight, operation, and seismic[**and wind**] forces required to select vibration isolators and seismic[**and wind**] restraints and for designing vibration isolation bases.

a. Coordinate design calculations with wind load calculations required for equipment mounted outdoors. Comply with requirements in other Sections for equipment mounted outdoors.

3. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, spring deflection changes, and seismic loads. Include certification that riser system was examined for excessive stress and that none exists.

Retain "Seismic(- and Wind)-Restraint Details" Subparagraph below only if seismic design requirements apply but calculations have not been made and details or charts on Drawings do not describe seismic restraints in detail. Retaining subparagraph requires Contractor to submit seismic-restraint delegated-design Drawings prepared by a professional engineer. Revise to suit local requirements.

4. Seismic[**- and Wind**]-Restraint Details:

a. Design Analysis: To support selection and arrangement of seismic[**and wind**] restraints. Include calculations of combined tensile and shear loads.
b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.

Retain first subparagraph below if Project includes equipment mounted outdoors.

c. Coordinate seismic-restraint and vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply with requirements in other Sections for equipment mounted outdoors.
d. Preapproval and Evaluation Documentation: By [**an evaluation service member of ICC-ES**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**], showing maximum ratings of restraint items and the basis for approval (tests or calculations).

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Show coordination of vibration isolation device installation and seismic bracing for HVAC piping and equipment with other systems and equipment in the vicinity, including other supports and restraints, if any.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

B. Qualification Data: For [**professional engineer**] [**and**] [**testing agency**].

Retain "Welding certificates" Paragraph below if retaining "Welding Qualifications" Paragraph in "Quality Assurance" Article.

C. Welding certificates.

Retain option in "Air-Mounting System Performance Certification" Paragraph below if authorities having jurisdiction require independent testing.

D. Air-Mounting System Performance Certification: Include natural frequency, load, and damping test data[**performed by an independent agency**].

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing.

E. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

Retain this article for restrained air-spring isolators.

A. Operation and Maintenance Data: For [**air-spring mounts**] [**and**] [**restrained-air-spring mounts**] to include in operation and maintenance manuals.

1.7 QUALITY ASSURANCE

If an independent testing agency is required, see Section 014000 "Quality Requirements" for general testing and inspecting agency qualification requirements. If additional control is needed, retain "Testing Agency Qualifications" Paragraph below to specify 29 CFR 1910.7. 29 CFR 1910.7 defines "NRTL" (nationally recognized testing laboratory) as it applies to testing and inspecting for safety, and lists, labels, or accepts equipment and materials that comply with certain OSHA criteria.

Retain "Testing Agency Qualifications" Paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article.

A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is an NRTL as defined by OSHA in 29 CFR 1910.7 and that is acceptable to authorities having jurisdiction.

B. Comply with seismic-restraint requirements in the IBC unless requirements in this Section are more stringent.

Retain "Welding Qualifications" Paragraph below if shop or field welding is required. If retaining, also retain "Welding certificates" Paragraph in "Informational Submittals" Article.

C. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

D. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval OPA number from OSHPD, preapproval by ICC-ES, or preapproval by another agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are unavailable, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

See Evaluations for more detailed information about controlling vibration, additional information on products described in this Section, illustrations, selection guides, and supplements to equipment schedules.

Coordinate specifications for products in this Section with structural engineer and with Drawings.

2.1 PERFORMANCE REQUIREMENTS

Retain "Wind-Restraint Loading" Paragraph below for outdoor equipment.

A. Wind-Restraint Loading:

Obtain values for items in subparagraphs below from Project structural engineer or from ASCE/SEI 7.

1. Basic Wind Speed: <**Insert value**>.
2. Building Classification Category: [**I**] [**II**] [**III**] [**IV**].
3. Minimum 10 lb/sq. ft. multiplied by maximum area of HVAC component projected on vertical plane normal to wind direction, and 45 degrees either side of normal.

B. Seismic-Restraint Loading:

Obtain values for items in subparagraphs below from Project structural engineer or from ASCE/SEI 7. If the code at Project site is other than the IBC or NFPA 5000, revise parameters to comply with applicable code.

Specify design spectral response acceleration at short periods (0.2 second) and at 1.0 second based on site class in "Site Class as Defined in the IBC" Subparagraph below. Typical values range from 2 to 200 percent. Design spectral response acceleration is required for seismic force calculations to size seismic restraints. For each seismic restraint, include component importance factor, component response modification factor, and component amplification factor in the HVAC Vibration-Control and Seismic-Restraint Device Schedule on Drawings.

1. Site Class as Defined in the IBC: [**A**] [**B**] [**C**] [**D**] [**E**] [**F**].

In "Assigned Seismic Use Group or Building Category as Defined in the IBC" Subparagraph below, retain Seismic Use Group or Building Category for Project structure from three classifications defined in the IBC.

2. Assigned Seismic Use Group or Building Category as Defined in the IBC: [**I**] [**II**] [**III**].

Retain "Component Importance Factor," "Component Response Modification Factor," and "Component Amplification Factor" subparagraphs below if these values are not included in the HVAC Vibration-Control and Seismic-Restraint Device Schedule on Drawings. Factors below often vary among supported equipment. However, it is possible to specify maximum values for these factors for various classes of equipment or for all equipment instead of scheduling each piece of equipment.

a. Component Importance Factor: [**1.0**] [**1.5**] <**Insert value**>.
b. Component Response Modification Factor: [**1.5**] [**2.5**] [**3.5**] [**5.0**] <**Insert value**>.
c. Component Amplification Factor: [**1.0**] [**2.5**] <**Insert value**>.

3. Design Spectral Response Acceleration at Short Periods (0.2 Second): <**Insert number**>.
4. Design Spectral Response Acceleration at 1.0-Second Period: <**Insert number**>.

See Evaluations for a discussion on seismic-restraint capacities and rating services.

5. Rated strengths, features, and applications shall be as defined in reports by [**an evaluation service member of ICC-ES**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**].

a. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least [**four**] <**Insert number**> times the maximum seismic forces to which they are subjected.

2.2 ELASTOMERIC ISOLATION PADS

Copy "Elastomeric Isolation Pads" Paragraph below and re-edit for each product.

The configuration and materials of elastomeric isolation pads depend on the equipment being supported. It is possible to have more than one type of elastomeric isolation pad on the same Project. Insert Drawing designation for each elastomeric isolation pad type required. Use these designations on Drawings to identify each product.

A. Elastomeric Isolation Pads: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. Ace Mountings Co., Inc.
   b. CADDY; a brand of nVent.
   c. California Dynamics Corporation.
   d. Isolation Technology, Inc.
   e. Kinetics Noise Control, Inc.
   f. Korfund.
   g. Mason Industries, Inc.
   h. Novia; A Division of C&P.
   i. Vibration Eliminator Co., Inc.
   j. Vibration Isolation.
   k. Vibration Management Corp.

2. Fabrication: Single or multiple layers of sufficient durometer stiffness for uniform loading over pad area.
3. Size: Factory or field cut to match requirements of supported equipment.

Verify availability of various pad materials and their properties with manufacturers.

4. Pad Material: Oil and water resistant with elastomeric properties.
5. Surface Pattern: [**Smooth**] [**Ribbed**] [**Waffle**] pattern.

Retain first subparagraph below if pad is infused with synthetic fibers.

6. Infused nonwoven cotton or synthetic fibers.

Retain first subparagraph below if galvanized-steel baseplates are adhered to the isolation pad to facilitate load distribution.

7. Load-bearing metal plates adhered to pads.

Retain "Sandwich-Core Material" Subparagraph below if pad has a sandwich-core material.

Copy "Sandwich-Core Material" Subparagraph below and re-edit for each sandwich-core material. Core materials may not be elastomeric. See the "Elastomeric Isolation Pads" Article in the Evaluations for more information.

8. Sandwich-Core Material: [**Resilient**] [**and**] [**elastomeric**] <**Insert compound**>.

Retain "Surface Pattern" Subparagraph below if the sandwich-core material has a surface pattern.

a. Surface Pattern: [**Smooth**] [**Ribbed**] [**Waffle**] pattern.

Retain subparagraph below if pad is infused with synthetic fibers.

b. Infused nonwoven cotton or synthetic fibers.

2.3 ELASTOMERIC ISOLATION MOUNTS

Copy "Double-Deflection, Elastomeric Isolation Mounts" Paragraph below and re-edit for each product.

The configuration and materials of elastomeric isolation mounts depend on the equipment being supported. It is possible to have more than one type of elastomeric isolation mount on the same Project. Insert drawing designation for each elastomeric isolation mount type required. Use these designations on Drawings to identify each product.

A. Double-Deflection, Elastomeric Isolation Mounts: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Ace Mountings Co., Inc.
b. CADDY; a brand of nVent.
c. California Dynamics Corporation.
d. Isolation Technology, Inc.
e. Kinetics Noise Control, Inc.
f. Korfund.
g. Mason Industries, Inc.
h. Novia; A Division of C&P.
i. Vibration Eliminator Co., Inc.
j. Vibration Isolation.
k. Vibration Management Corp.

2. Mounting Plates:

a. Top Plate: Encapsulated steel load transfer top plates, factory drilled and threaded[**with threaded studs or bolts**].

Retain "Baseplate" Subparagraph below if the elastomeric mount being specified has a baseplate.

b. Baseplate: Encapsulated steel bottom plates with holes provided for anchoring to support structure.

3. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.4 RESTRAINED ELASTOMERIC ISOLATION MOUNTS

Copy "Restrained Elastomeric Isolation Mounts" Paragraph below and re-edit for each product.

The configuration and materials of restrained elastomeric isolation mounts depend on the equipment being supported. It is possible to have more than one type of restrained elastomeric isolation mount on the same Project. Insert drawing designation for each restrained elastomeric isolation mount type required. Use these designations on Drawings to identify each product.

A. Restrained Elastomeric Isolation Mounts: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Ace Mountings Co., Inc.
   b. CADDY; a brand of nVent.
   c. California Dynamics Corporation.
   d. Isolation Technology, Inc.
   e. Kinetics Noise Control, Inc.
   f. Korfund.
   g. Mason Industries, Inc.
   h. Novia; A Division of C&P.
   i. Vibration Eliminator Co., Inc.
   j. Vibration Isolation.
   k. Vibration Management Corp.

2. Description: All-directional isolator with seismic restraints containing two separate and opposing elastomeric elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.

   a. Housing: Cast-ductile iron or welded steel.
   b. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.5 OPEN-SPRING ISOLATORS

Copy "Freestanding, Laterally Stable, Open-Spring Isolators" Paragraph below and re-edit for each product.

The configuration and materials of open-spring isolators depend on the equipment being supported. It is possible to have more than one type of open-spring isolator on the same Project. Insert drawing designation for each open-spring isolator type required. Use these designations on Drawings to identify each product.

A. Freestanding, Laterally Stable, Open-Spring Isolators: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Ace Mountings Co., Inc.

b. CADDY; a brand of nVent.
c. California Dynamics Corporation.
d. Isolation Technology, Inc.
e. Kinetics Noise Control, Inc.
f. Korfund.
g. Mason Industries, Inc.
h. Novia; A Division of C&P.
i. Vibration Eliminator Co., Inc.
j. Vibration Isolation.
k. Vibration Management Corp.

2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Baseplates: Factory-drilled steel plate for bolting to structure with an elastomeric isolator pad attached to the underside. Baseplates shall limit floor load to 500 psig.
7. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

2.6 HOUSED-SPRING ISOLATORS

Copy "Freestanding, Laterally Stable, Open-Spring Isolators in Two-Part Telescoping Housing" Paragraph below and re-edit for each product.

The configuration and materials of housed-spring isolators depend on the equipment being supported. It is possible to have more than one type of housed-spring isolator on the same Project. Insert drawing designation for each housed-spring isolator type required. Use these designations on Drawings to identify each product.

A. Freestanding, Laterally Stable, Open-Spring Isolators in Two-Part Telescoping Housing: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Ace Mountings Co., Inc.
b. CADDY; a brand of nVent.
c. California Dynamics Corporation.
d. Isolation Technology, Inc.
e. Kinetics Noise Control, Inc.
f. Korfund.
g. Mason Industries, Inc.
h. Vibration Eliminator Co., Inc.
i. Vibration Isolation.
j. Vibration Management Corp.

2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators.

    a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.
    b. Top housing with [**attachment and leveling bolt**] [**threaded mounting holes and internal leveling device**] [**elastomeric pad**].

2.7 RESTRAINED-SPRING ISOLATORS

Copy "Freestanding, Laterally Stable, Open-Spring Isolators with Vertical-Limit Stop Restraint" Paragraph below and re-edit for each product.

The configuration and materials of restrained-spring isolators depend on the equipment being supported. It is possible to have more than one type of restrained-spring isolator on the same Project. Insert drawing designation for each restrained-spring isolator type required. Use these designations on Drawings to identify each product.

A. Freestanding, Laterally Stable, Open-Spring Isolators with Vertical-Limit Stop Restraint: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Ace Mountings Co., Inc.
    b. CADDY; a brand of nVent.
    c. California Dynamics Corporation.
    d. Isolation Technology, Inc.
    e. Kinetics Noise Control, Inc.
    f. Korfund.
    g. Mason Industries, Inc.
    h. Novia; A Division of C&P.
    i. Vibration Eliminator Co., Inc.
    j. Vibration Isolation.
    k. Vibration Management Corp.

2. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.

    a. Base with holes for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.
    b. Top plate with [**threaded mounting holes**] [**elastomeric pad**].
    c. Internal leveling bolt that acts as blocking during installation.

3. Restraint: Limit stop as required for equipment and authorities having jurisdiction.
4. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
5. Minimum Additional Travel: 50 percent of the required deflection at rated load.
6. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
7. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2.8 HOUSED-RESTRAINED-SPRING ISOLATORS

Copy "Freestanding, Steel, Open-Spring Isolators with Vertical-Limit Stop Restraint in Two-Part Telescoping Housing" Paragraph below and re-edit for each product.

The configuration and materials of housed-restrained-spring isolators depend on the equipment being supported. It is possible to have more than one type of housed-restrained-spring isolator on the same Project. Insert drawing designation for each housed-restrained-spring isolator type required. Use these designations on Drawings to identify each product.

A. Freestanding, Steel, Open-Spring Isolators with Vertical-Limit Stop Restraint in Two-Part Telescoping Housing: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Ace Mountings Co., Inc.
   b. CADDY; a brand of nVent.
   c. California Dynamics Corporation.
   d. Isolation Technology, Inc.
   e. Kinetics Noise Control, Inc.
   f. Korfund.
   g. Mason Industries, Inc.
   h. Vibration Eliminator Co., Inc.
   i. Vibration Isolation.
   j. Vibration Management Corp.

2. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators. Housings are equipped with [**adjustable**] [**non-adjustable**] snubbers to limit vertical movement.

   a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.
   b. Threaded top housing with adjustment bolt and cap screw to fasten and level equipment.

3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2.9 PIPE-RISER RESILIENT SUPPORT

Copy "Description" Paragraph below and re-edit for each product.

The configuration and materials of pipe-riser resilient supports depend on the equipment being supported. It is possible to have more than one type of pipe-riser resilient support on the same Project. Insert drawing designation for each pipe-riser resilient support type required. Use these designations on Drawings to identify each product.

A. Description: All-directional, acoustical pipe anchor consisting of two steel tubes separated by a minimum 1/2-inch-thick neoprene <**Insert drawing designation**>.

1. Vertical-Limit Stops: Steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions.
2. Maximum Load Per Support: 500 psigon isolation material providing equal isolation in all directions.

2.10 RESILIENT PIPE GUIDES

Copy "Description" Paragraph below and re-edit for each product.

The configuration and materials of resilient pipe guides depend on the equipment being supported. It is possible to have more than one type of resilient pipe guide on the same Project. Insert drawing designation for each resilient pipe guide type required. Use these designations on Drawings to identify each product.

A. Description: Telescopic arrangement of two steel tubes or post and sleeve arrangement separated by a minimum 1/2-inch-thick neoprene <**Insert drawing designation**>.

Retain "Factory-Set Height Guide with Shear Pin" Subparagraph below where vertical motion due to pipe expansion and contraction is required and clearances are not readily visible.

1. Factory-Set Height Guide with Shear Pin: Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.11 AIR-SPRING ISOLATORS

Copy "Freestanding, Single or Multiple, Compressed-Air Bellows" Paragraph below and re-edit for each product.

The configuration and materials of air-spring isolators depend on the equipment being supported. It is possible to have more than one type of air-spring isolator on the same Project. Insert drawing designation for each air-spring isolator type required. Use these designations on Drawings to identify each product.

A. Freestanding, Single or Multiple, Compressed-Air Bellows: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. CADDY; a brand of nVent.
b. Firestone Industrial Products Company.
c. Mason Industries, Inc.

2. Bellows Assembly: Upper and lower powder-coated steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows or similar elastomeric material.
3. Maximum Natural Frequency: 3 Hz.
4. Operating Pressure Range: 25 to 100 psig.
5. Burst Pressure: At least three times manufacturer's published maximum operating pressure.

Retain subparagraph below if air springs are mounted independent of each other and are not supplied by a constant pressure-regulated air supply.

6. Tank valves.

2.12 RESTRAINED-AIR-SPRING ISOLATORS

Copy "Freestanding, Single or Multiple, Compressed-Air Bellows with Vertical-Limit Stop Restraint" Paragraph below and re-edit for each product.

The configuration and materials of restrained-air-spring isolators depend on the equipment being supported. It is possible to have more than one type of restrained-air-spring isolator on the same Project. Insert drawing designation for each restrained-air-spring isolator type required. Use these designations on Drawings to identify each product.

A. Freestanding, Single or Multiple, Compressed-Air Bellows with Vertical-Limit Stop Restraint: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. CADDY; a brand of nVent.
   b. Firestone Industrial Products Company.
   c. Mason Industries, Inc.

2. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.

   a. Base with holes for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.
   b. Top plate with [**threaded mounting holes**] [**elastomeric pad**].
   c. Internal leveling bolt that acts as blocking during installation.

3. Restraint: Limit stop as required for equipment and authorities having jurisdiction.
4. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
5. Minimum Additional Travel: 50 percent of the required deflection at rated load.
6. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
7. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

8. Bellows Assembly: Upper and lower powder-coated steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows or similar elastomeric material.
9. Maximum Natural Frequency: 3 Hz.
10. Operating Pressure Range: 25 to 100 psig.
11. Burst Pressure: At least three times manufacturer's published maximum operating pressure.

Retain subparagraph below if air springs are mounted independent of each other and are not supplied by a constant pressure-regulated air supply.

12. Tank valves.

2.13 ELASTOMERIC HANGERS

Copy "Elastomeric Mount in a Steel Frame with Upper and Lower Steel Hanger Rods" Paragraph below and re-edit for each product.

The configuration and materials of elastomeric hangers depend on the equipment being supported. It is possible to have more than one type of elastomeric hanger on the same Project. Insert drawing designation for each elastomeric hanger type required. Use these designations on Drawings to identify each product.

A. Elastomeric Mount in a Steel Frame with Upper and Lower Steel Hanger Rods: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Ace Mountings Co., Inc.
   b. CADDY; a brand of nVent.
   c. California Dynamics Corporation.
   d. Kinetics Noise Control, Inc.
   e. Mason Industries, Inc.
   f. Novia; A Division of C&P.
   g. Vibration Eliminator Co., Inc.
   h. Vibration Isolation.
   i. Vibration Management Corp.

2. Frame: Steel, fabricated with a connection for an upper threaded hanger rod and an opening on the underside to allow for a maximum of 30 degrees of angular lower hanger-rod misalignment without binding or reducing isolation efficiency.
3. Dampening Element: Molded, oil-resistant rubber, neoprene, or other elastomeric material with a projecting bushing for the underside opening preventing steel to steel contact.

2.14 SPRING HANGERS

Copy "Combination Coil-Spring and Elastomeric-Insert Hanger with Spring and Insert in Compression" Paragraph below and re-edit for each product.

The configuration and materials of spring hangers depend on the equipment being supported. It is possible to have more than one type of spring hanger on the same Project. Insert drawing designation for each spring hanger type required. Use these designations on Drawings to identify each product.

A. Combination Coil-Spring and Elastomeric-Insert Hanger with Spring and Insert in Compression: <**Insert drawing designation**>.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. Ace Mountings Co., Inc.
    b. CADDY; a brand of nVent.
    c. California Dynamics Corporation.
    d. Kinetics Noise Control, Inc.
    e. Mason Industries, Inc.
    f. Novia; A Division of C&P.
    g. Vibration Eliminator Co., Inc.
    h. Vibration Isolation.
    i. Vibration Management Corp.

2. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
7. Elastomeric Element: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.

Retain "Adjustable Vertical Stop" Subparagraph below if a vertical-limit stop is required.

8. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
9. Self-centering hanger-rod cap to ensure concentricity between hanger rod and support spring coil.

2.15 SNUBBERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. CADDY; a brand of nVent.
2. Kinetics Noise Control, Inc.
3. Mason Industries, Inc.
4. Vibration Management Corp.

B. Description: Factory fabricated using welded structural-steel shapes and plates, anchor bolts, and replaceable resilient isolation washers and bushings.

1. Anchor bolts for attaching to concrete shall be seismic-rated, drill-in, and stud-wedge or female-wedge type.
2. Resilient Isolation Washers and Bushings: Oil- and water-resistant neoprene.
3. Maximum 1/4-inch air gap, and minimum 1/4-inch-thick resilient cushion.

Metal framing systems are specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

2.16 RESTRAINT CHANNEL BRACINGS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. B-line, an Eaton business.
2. CADDY; a brand of nVent.
3. Hilti, Inc.

B. Description: MFMA-4, shop- or field-fabricated bracing assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; rated in tension, compression, and torsion forces.

2.17 RESTRAINT CABLES

A. Manufacturers: Subject to compliance with requirements, provide products by the following:

1. CADDY; a brand of nVent.

B. Restraint Cables: [**ASTM A603 galvanized**] [**ASTM A492 stainless**]-steel cables. End connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; with a minimum of two clamping bolts for cable engagement.

2.18 SEISMIC-RESTRAINT ACCESSORIES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. B-line, an Eaton business.
2. CADDY; a brand of nVent.

Retain "Hanger-Rod Stiffener" Paragraph below for strengthening resistance of hanger rods against seismic forces that may cause buckling of rods; delete if detailed on Drawings. Use with either channel- or cable-type bracing assemblies when required to counter seismic forces. Detail fabrication and indicate locations on Drawings.

B. Hanger-Rod Stiffener: [**Steel tube or steel slotted-support-system sleeve with internally bolted connections**] [**Reinforcing steel angle clamped**] to hanger rod.

C. Hinged and Swivel Brace Attachments: Multifunctional steel connectors for attaching hangers to [**rigid channel bracings**] [**and**] [**restraint cables**].

D. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchor bolts and studs.

E. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings, and matched to type and size of attachment devices used.

F. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

2.19 MECHANICAL ANCHOR BOLTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. B-line, an Eaton business.
2. Hilti, Inc.
3. Mason Industries, Inc.
4. Powers Fasteners.
5. Simpson Strong-Tie Co., Inc.

Expansion-type anchor bolts are not permitted by ASCE/SEI 7 for nonisolated equipment in excess of 10 hp (7.46 kW).

B. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E488.

2.20 ADHESIVE ANCHOR BOLTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. B-line, an Eaton business.
2. Hilti, Inc.
3. Mason Industries, Inc.
4. Powers Fasteners.
5. Simpson Strong-Tie Co., Inc.

B. Adhesive Anchor Bolts: Drilled-in and capsule anchor system containing PVC or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E488.

2.21 VIBRATION ISOLATION EQUIPMENT BASES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. CADDY; a brand of nVent.
2. California Dynamics Corporation.
3. Kinetics Noise Control, Inc.
4. Mason Industries, Inc.
5. Novia; A Division of C&P.
6. Vibration Eliminator Co., Inc.
7. Vibration Isolation.
8. Vibration Management Corp.

B. Steel Rails: Factory-fabricated, welded, structural-steel rails.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide rails.

Retain first subparagraph below if steel rails are required for pumps.

a. Include supports for suction and discharge elbows for pumps.

2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A36/A36M. Rails shall have shape to accommodate supported equipment.
3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

C. Steel Bases: Factory-fabricated, welded, structural-steel bases and rails.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.

Retain first subparagraph below if steel bases are required for pumps.

a. Include supports for suction and discharge elbows for pumps.

2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A36/A36M. Bases shall have shape to accommodate supported equipment.
3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

D. Concrete Inertia Base: [**Factory-fabricated**] [**or**] [**field-fabricated**], welded, structural-steel bases and rails ready for placement of cast-in-place concrete.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.

Retain first subparagraph below if inertia bases are required for pumps.

a. Include supports for suction and discharge elbows for pumps.

2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A36/A36M. Bases shall have shape to accommodate supported equipment.
3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
4. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.

2.22 RESTRAINED ISOLATION ROOF-CURB RAILS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. CADDY; a brand of nVent.
2. California Dynamics Corporation.
3. Kinetics Noise Control, Inc.
4. Novia; A Division of C&P.
5. Thybar Corporation.
6. Vibration Eliminator Co., Inc.
7. Vibration Management Corp.

B. Description: Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment and to withstand seismic[**and wind**] forces.

C. Upper Frame: The upper frame shall provide continuous support for equipment and shall be captive to resiliently resist seismic[**and wind**] forces.

D. Lower Support Assembly: The lower support assembly shall be formed sheet metal section containing adjustable and removable steel springs that support the upper frame. The lower support assembly shall have a means for attaching to building structure and a wood nailer for attaching roof materials, and shall be insulated with a minimum of 2 inches of rigid, glass-fiber insulation on inside of assembly. Adjustable, restrained-spring isolators shall be mounted on elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with the integrity of the roof.

E. Snubber Bushings: All-directional, elastomeric snubber bushings at least 1/4 inch thick.

F. Water Seal: Galvanized sheet metal with EPDM seals at corners, attached to upper support frame, extending down past wood nailer of lower support assembly, and counterflashed over roof materials.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and equipment to receive vibration isolation and seismic[- **and wind**]-control devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by [**an evaluation service member of ICC-ES**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**].

Indicate on Drawings, by details, schedules, or a combination of both, the locations where hanger rods for individual pipes and hanger rods for trapeze hangers require hanger-rod stiffeners.

B. Hanger-Rod Stiffeners: Install hanger-rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.

C. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength is adequate to carry present and future static and seismic loads within specified loading limits.

3.3 VIBRATION CONTROL AND SEISMIC-RESTRAINT DEVICE INSTALLATION

A. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 033000 "Cast-in-Place Concrete."

B. Installation of vibration isolators must not cause any change of position of equipment, piping, or ductwork resulting in stresses or misalignment.

C. Comply with requirements in Section 077200 "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.

D. Equipment Restraints:

Indicate type and quantity of snubbers described in first subparagraph below on Drawings or in the HVAC Vibration-Control and Seismic-Restraint Device Schedule on Drawings.

1. Install seismic snubbers on HVAC equipment mounted on vibration isolators. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.

2. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
3. Install seismic-restraint devices using methods approved by [**an evaluation service member of ICC-ES**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**] that provides required submittals for component.

E. Piping Restraints:

1. Comply with requirements in MSS SP-127.

In first subparagraph below, options for 40 and 80 feet (12 and 24 m) are recommended by MSS SP-127. Revise these dimensions based on the configuration of piping.

2. Space lateral supports a maximum of [**40 feet**] <**Insert dimension**> o.c., and longitudinal supports a maximum of [**80 feet**] <**Insert dimension**> o.c.
3. Brace a change of direction longer than 12 feet.

F. Install cables so they do not bend across edges of adjacent equipment or building structure.

G. Install seismic-restraint devices using methods approved by [**an evaluation service member of ICC-ES**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**] that provides required submittals for component.

H. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.

I. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.

J. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.

K. Drilled-in Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
5. Set anchors to manufacturer's recommended torque, using a torque wrench.
6. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

3.4 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

Coordinate this article with Drawings.

A. Install flexible connections in piping where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment. Comply with requirements in Section 232113 "Hydronic Piping" for piping flexible connections.

3.5 FIELD QUALITY CONTROL

Retain "Testing Agency" and "Perform tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph, or if retaining "Perform tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain "Perform tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

B. Perform tests and inspections.

C. Tests and Inspections:

1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
2. Schedule test with Owner, through Architect, before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least seven days' advance notice.
3. Obtain Architect's approval before transmitting test loads to structure. Provide temporary load-spreading members.
4. Test at least [**four**] <**Insert number**> of each type and size of installed anchors and fasteners selected by Architect.
5. Test to 90 percent of rated proof load of device.
6. Measure isolator restraint clearance.
7. Measure isolator deflection.
8. Verify snubber minimum clearances.

Retain subparagraph below if restrained-air-spring isolators are included in Project.

9. Test and adjust restrained-air-spring isolator controls and safeties.

D. Remove and replace malfunctioning units and retest as specified above.

E. Prepare test and inspection reports.

3.6 ADJUSTING

A. Adjust isolators after piping system is at operating weight.

B. Adjust limit stops on restrained-spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

3.7 AIR-SPRING ISOLATOR INSTALLATION

Retain "Independent Isolator Installation" Paragraph below if air springs are mounted independent of each other and are not supplied by a constant pressure-regulated air supply.

A. Independent Isolator Installation:

1. Install tank valve into each air isolator.
2. Inflate each isolator to [**height**] [**and**] [**pressure**] specified on Drawings.

Retain "Pressure-Regulated Isolator Installation" Paragraph below if air springs are supplied with a constant pressure-regulated air supply.

B. Pressure-Regulated Isolator Installation:

1. Coordinate the constant pressure-regulated air supply to air springs with the requirements for piping and connections specified in Section 221513 "General-Service Compressed-Air Piping."
2. Connect all pressure regulators to a single dry, filtered [**facility**] [**constant**] air supply.
3. Inflate isolators to [**height**] [**and**] [**or**] [**pressure**] specified on Drawings.

3.8 VIBRATION ISOLATION EQUIPMENT BASES INSTALLATION

A. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 033000 "Cast-in-Place Concrete."

END OF SECTION 230548

SECTION 230553 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Equipment labels.
2. Warning signs and labels.
3. Pipe labels.
4. Duct labels.
5. Stencils.
6. Valve tags.

7. Warning tags.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Samples: For color, letter style, and graphic representation required for each identification material and device.

C. Equipment Label Schedule: Include a listing of all equipment to be labeled with the proposed content for each label.

D. Valve numbering scheme.

E. Valve Schedules: For each piping system to include in maintenance manuals.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 EQUIPMENT LABELS

Copy paragraphs below and revise for each product.

A. Metal Labels for Equipment:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Brady Corporation.
b. Brimar Industries, Inc.
c. Carlton Industries, LP.
d. Champion America.
e. Craftmark Pipe Markers.
f. emedco.
g. Kolbi Pipe Marker Co.
h. LEM Products Inc.
i. Marking Services, Inc.

Retain multiple material options in "Material and Thickness" Subparagraph below to allow Contractor to retain most cost-effective material.

2. Material and Thickness: [**Brass, 0.032-inch**] [**stainless steel, 0.025-inch**] [**aluminum, 0.032-inch**] [**or**] [**anodized aluminum, 0.032-inch**] minimum thickness, and having predrilled or stamped holes for attachment hardware.
3. Letter Color: [**Black**] [**Blue**] [**Red**] [**White**] [**Yellow**] <**Insert color**>.
4. Background Color: [**Black**] [**Blue**] [**Red**] [**White**] [**Yellow**] <**Insert color**>.

5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
6. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.
7. Fasteners: Stainless-steel [**rivets**] [**or**] [**self-tapping screws**].
8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Plastic Labels for Equipment:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Brady Corporation.
    b. Brimar Industries, Inc.
    c. Carlton Industries, LP.
    d. Champion America.
    e. Craftmark Pipe Markers.
    f. emedco.
    g. Kolbi Pipe Marker Co.
    h. LEM Products Inc.
    i. Marking Services, Inc.

2. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, [**1/16 inch**] [**1/8 inch**] <**Insert dimension**> thick, and having predrilled holes for attachment hardware.
3. Letter Color: [**Black**] [**Blue**] [**Red**] [**White**] [**Yellow**] <**Insert color**>.
4. Background Color: [**Black**] [**Blue**] [**Red**] [**White**] [**Yellow**] <**Insert color**>.
5. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
6. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
7. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.
8. Fasteners: Stainless-steel [**rivets**] [**or**] [**self-tapping screws**].
9. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

In "Label Content" Paragraph below, the objective of labeling equipment is to coordinate it with Drawings, including plans, details, and schedules. This will allow other information, such as capacities and operating characteristics, to be obtained.

C. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), and the Specification Section number and title where equipment is specified.

D. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch bond paper. Tabulate equipment identification number, and identify Drawing numbers where equipment is indicated (plans, details, and schedules) and the Specification Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.2 WARNING SIGNS AND LABELS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Brady Corporation.
2. Brimar Industries, Inc.
3. Carlton Industries, LP.
4. Champion America.
5. Craftmark Pipe Markers.
6. emedco.
7. LEM Products Inc.
8. Marking Sevices Inc.
9. National Marker Company.
10. Seton Identification Products; a Brady Corporation company.

B. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, [**1/16 inch**] [**1/8 inch**] <**Insert dimension**> thick, and having predrilled holes for attachment hardware.

C. Letter Color: [**Black**] [**Blue**] [**Red**] [**White**] [**Yellow**] <**Insert color**>.

D. Background Color: [**Black**] [**Blue**] [**Red**] [**White**] [**Yellow**] <**Insert color**>.

E. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

F. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

G. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.

H. Fasteners: Stainless-steel [**rivets**] [**or**] [**self-tapping screws**].

I. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

In "Label Content" Paragraph below, the objective of labeling equipment is to coordinate it with Drawings, including plans, details, and schedules. This will allow other information, such as capacities and operating characteristics, to be obtained.

J. Label Content: Include caution and warning information plus emergency notification instructions.

2.3 PIPE LABELS

Retain this article if labeling devices identify some or all piping. Identification of piping by color-coded painting is covered in "Pipe Label Installation" Article.

Do not use pipe labels or plastic tapes for bare pipes conveying fluids at temperatures of 125 deg F (52 deg C) or higher.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Actioncraft Products, Inc.; a division of Industrial Test Equipment Co., Inc.
2. Brady Corporation.
3. Brimar Industries, Inc.
4. Carlton Industries, LP.
5. Champion America.
6. Craftmark Pipe Markers.
7. emedco.
8. Kolbi Pipe Marker Co.
9. LEM Products Inc.
10. Marking Sevices Inc.

B. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction according to ASME A13.1.

C. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to [**partially cover**] [**cover full**] circumference of pipe and to attach to pipe without fasteners or adhesive.

D. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.

E. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings; also include pipe size and an arrow indicating flow direction.

1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions or as separate unit on each pipe label to indicate flow direction.

Retain second option in "Lettering Size" Subparagraph below if visibility due to distance from piping is an issue.

2. Lettering Size: [**Size letters according to ASME A13.1 for piping**] [**At least 1/2 inch for viewing distances up to 72 inches and proportionately larger lettering for greater viewing distances**].

2.4 DUCT LABELS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Brady Corporation.
2. Brimar Industries, Inc.

3. Carlton Industries, LP.
4. Champion America.
5. Craftmark Pipe Markers.
6. emedco.
7. Kolbi Pipe Marker Co.
8. LEM Products Inc.
9. Marking Sevices Inc.

B. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, [**1/16 inch**] [**1/8 inch**] <**Insert dimension**> thick, and having predrilled holes for attachment hardware.

C. Letter Color: [**Black**] [**Blue**] [**Red**] [**White**] [**Yellow**] <**Insert color**>.

D. Background Color: [**Black**] [**Blue**] [**Red**] [**White**] [**Yellow**] <**Insert color**>.

E. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

F. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

G. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.

H. Fasteners: Stainless-steel [**rivets**] [**or**] [**self-tapping screws**].

I. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

J. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings; also include duct size and an arrow indicating flow direction.

1. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions or as separate unit on each duct label to indicate flow direction.

2.5 STENCILS

A. Stencils for Piping:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Brimar Industries, Inc.
b. Carlton Industries, LP.
c. Champion America.
d. Craftmark Pipe Markers.
e. Kolbi Pipe Marker Co.

Retain second option in "Lettering Size" Subparagraph below if visibility due to distance from piping is an issue.

2. Lettering Size: [**Size letters according to ASME A13.1 for piping**] [**At least 1/2 inch for viewing distances up to 72 inches and proportionately larger lettering for greater viewing distances**].
3. Stencil Material: [**Aluminum**] [**Brass**] [**Fiberboard**] [**Fiberboard or metal**] <**Insert material**>.
4. Stencil Paint: Exterior, gloss, [**alkyd enamel**] [**acrylic enamel**] <**Insert paint type**> in colors complying with recommendations in ASME A13.1 unless otherwise indicated. Paint may be in pressurized spray-can form.
5. Identification Paint: Exterior, [**alkyd enamel**] [**acrylic enamel**] <**Insert paint type**> in colors according to ASME A13.1 unless otherwise indicated. Paint may be in pressurized spray-can form.

B. Stencils for Ducts:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Brimar Industries, Inc.
   b. Carlton Industries, LP.
   c. Champion America.
   d. Craftmark Pipe Markers.
   e. Kolbi Pipe Marker Co.

2. Lettering Size: Minimum letter height of 1-1/4 inches for viewing distances up to 15 feet and proportionately larger lettering for greater viewing distances.
3. Stencil Material: [**Aluminum**] [**Brass**] [**Fiberboard**] [**Fiberboard or metal**] <**Insert material**>.
4. Stencil Paint: Exterior, gloss, [**alkyd enamel**] [**acrylic enamel**] <**Insert paint type**>. Paint may be in pressurized spray-can form.
5. Identification Paint: Exterior, [**alkyd enamel**] [**acrylic enamel**] <**Insert paint type**>. Paint may be in pressurized spray-can form.

C. Stencils for Access Panels and Door Labels, Equipment Labels, and Similar Operational Instructions:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Brimar Industries, Inc.
   b. Carlton Industries, LP.
   c. Champion America.
   d. Craftmark Pipe Markers.
   e. Kolbi Pipe Marker Co.

2. Lettering Size: Minimum letter height of 1/2 inch for viewing distances up to 72 inches and proportionately larger lettering for greater viewing distances.
3. Stencil Material: [**Aluminum**] [**Brass**] [**Fiberboard**] [**Fiberboard or metal**] <**Insert material**>.

4. Stencil Paint: Exterior, gloss, [**alkyd enamel**] [**acrylic enamel**] <**Insert paint type**>. Paint may be in pressurized spray-can form.
5. Identification Paint: Exterior, [**alkyd enamel**] [**acrylic enamel**] <**Insert paint type**>. Paint may be in pressurized spray-can form.

2.6 VALVE TAGS

Retain requirement in "Action Submittals" Article to submit numbering scheme for approval.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Actioncraft Products, Inc.; a division of Industrial Test Equipment Co., Inc.
2. Brady Corporation.
3. Brimar Industries, Inc.
4. Carlton Industries, LP.
5. Champion America.
6. Craftmark Pipe Markers.
7. emedco.
8. Kolbi Pipe Marker Co.
9. LEM Products Inc.
10. Marking Sevices Inc.

B. Description: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.

1. Tag Material: [**Brass, 0.032-inch**] [**stainless steel, 0.025-inch**] [**aluminum, 0.032-inch**] [**or**] [**anodized aluminum, 0.032-inch**] minimum thickness, and having predrilled or stamped holes for attachment hardware.
2. Fasteners: Brass [**wire-link chain**] [**or**] [**beaded chain**] [**or**] [**S-hook**].

C. Valve Schedules: For each piping system, on 8-1/2-by-11-inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.

1. Valve-tag schedule shall be included in operation and maintenance data.

2.7 WARNING TAGS

Copy paragraphs below and revise for each product.

The configuration and materials of elastomeric isolation pads depends on the equipment being supported. It is possible to have more than one type of elastomeric isolation pad on same Project. Insert Drawing designation for each elastomeric isolation pad type required. Use these designations on Drawings to identify each product.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Brady Corporation.
2. Brimar Industries, Inc.
3. Carlton Industries, LP.
4. Champion America.
5. Craftmark Pipe Markers.
6. emedco.
7. Kolbi Pipe Marker Co.
8. LEM Products Inc.
9. Marking Sevices Inc.

B. Description: Preprinted or partially preprinted accident-prevention tags of plasticized card stock with matte finish suitable for writing.

1. Size: [**3 by 5-1/4 inches minimum**] [**Approximately 4 by 7 inches**] <**Insert size**>.
2. Fasteners: [**Brass grommet and wire**] [**Reinforced grommet and wire or string**].
3. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."
4. Color: Safety-yellow background with black lettering.

PART 3 - EXECUTION

3.1 PREPARATION

A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

3.2 GENERAL INSTALLATION REQUIREMENTS

A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.

B. Coordinate installation of identifying devices with locations of access panels and doors.

C. Install identifying devices before installing acoustical ceilings and similar concealment.

3.3 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment.

B. Locate equipment labels where accessible and visible.

3.4 PIPE LABEL INSTALLATION

Retain "Piping Color Coding" Paragraph below to identify piping systems by color-coded painting. Labels will still be required to identify service, pipe size, and flow direction.

A. Piping Color Coding: Painting of piping is specified in [**Section 099123 "Interior Painting."**] [**Section 099600 "High-Performance Coatings."**]

Retain "Stenciled Pipe Label Option" Paragraph below only if stenciled labels are permitted.

B. Stenciled Pipe Label Option: Stenciled labels may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels, complying with ASME A13.1,[**with painted, color-coded bands or rectangles**] on each piping system.

1. Identification Paint: Use for contrasting background.
2. Stencil Paint: Use for pipe marking.

Revise "Pipe Label Locations" Paragraph below to suit Project.

C. Pipe Label Locations: Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations and on both sides of through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of [**50 feet**] <**Insert dimension**> along each run. Reduce intervals to [**25 feet**] <**Insert dimension**> in areas of congested piping and equipment.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

"Directional Flow Arrows" Paragraph below is in compliance with ASME A13.1.

D. Directional Flow Arrows: Arrows shall be used to indicate direction of flow in pipes, including pipes where flow is allowed in both directions.

E. Pipe Label Color Schedule:

Retain first option in the following three subparagraphs below if water does not contain toxic or corrosive fluids per ASME A13.1.

1. Chilled-Water Piping: [**White letters on a safety-green background**] [**Black letters on a safety-orange background**] <**Insert colors**>.
2. Condenser-Water Piping: [**White letters on a safety-green background**] [**Black letters on a safety-orange background**] <**Insert colors**>.
3. Heating Water Piping: [**White letters on a safety-green background**] [**Black letters on a safety-orange background**] <**Insert colors**>.

Retain first option in "Refrigerant Piping" Subparagraph below if refrigerant fluid is toxic or corrosive. All other options listed are user-defined options per ASME A13.1.

4. Refrigerant Piping: [**Black letters on a safety-orange background**] [**White letters on a safety-purple background**] [**Black letters on a safety-white background**] [**White**

letters on a safety-gray background] [**White letters on a safety-black background**] <**Insert colors**>.

Retain, in subparagraphs below, one of the user-defined color schemes per ASME A13.1.

5. Low-Pressure Steam Piping: [**White letters on a safety-purple background**] [**Black letters on a safety-white background**] [**White letters on a safety-gray background**] [**White letters on a safety-black background**] <**Insert colors**>.
6. High-Pressure Steam Piping: [**White letters on a safety-purple background**] [**Black letters on a safety-white background**] [**White letters on a safety-gray background**] [**White letters on a safety-black background**] <**Insert colors**>.
7. Steam Condensate Piping: [**White letters on a safety-purple background**] [**Black letters on a safety-white background**] [**White letters on a safety-gray background**] [**White letters on a safety-black background**] <**Insert colors**>.

3.5 DUCT LABEL INSTALLATION

A. Install [**plastic-laminated**] [**self-adhesive**] duct labels with permanent adhesive on air ducts in the following color codes:

1. [**Blue**] <**Insert color**>: For cold-air supply ducts.
2. [**Yellow**] <**Insert color**>: For hot-air supply ducts.
3. [**Green**] <**Insert color**>: For exhaust-, outside-, relief-, return-, and mixed-air ducts.

Retain "Stenciled Duct Label Option" Paragraph below only if stenciled labels are permitted.

B. Stenciled Duct Label Option: Stenciled labels showing service and flow direction may be provided instead of plastic-laminated duct labels, at Installer's option.

C. Locate labels near points where ducts enter into and exit from concealed spaces and at maximum intervals of [**50 feet**] <**Insert dimension**> in each space where ducts are exposed or concealed by removable ceiling system.

3.6 VALVE-TAG INSTALLATION

Revise this article as required to delete an entire piping system from tagging or other changes. A schedule is helpful for complex projects. Retain and revise first paragraph below if a schedule is prepared.

A. Install tags on valves and control devices in piping systems, except check valves, valves within factory-fabricated equipment units, shutoff valves, faucets, convenience and lawn-watering hose connections, and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.

B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:

Other valve-tag sizes and shapes may be available if required.

1. Valve-Tag Size and Shape:

    a. Chilled Water: [**1-1/2 inches**] [**2 inches**], [**round**] [**square**] <**Insert shape**>.

b. Condenser Water: [**1-1/2 inches**] [**2 inches**], [**round**] [**square**] <**Insert shape**>.
c. Refrigerant: [**1-1/2 inches**] [**2 inches**], [**round**] [**square**] <**Insert shape**>.
d. Hot Water: [**1-1/2 inches**] [**2 inches**], [**round**] [**square**] <**Insert shape**>.
e. Gas: [**1-1/2 inches**] [**2 inches**], [**round**] [**square**] <**Insert shape**>.
f. Low-Pressure Steam: [**1-1/2 inches**] [**2 inches**], [**round**] [**square**] <**Insert shape**>.
g. High-Pressure Steam: [**1-1/2 inches**] [**2 inches**], [**round**] [**square**] <**Insert shape**>.
h. Steam Condensate: [**1-1/2 inches**] [**2 inches**], [**round**] [**square**] <**Insert shape**>.

Tag colors, if used, should follow the color schemes defined by ASME A13.1.

2. Valve-Tag Colors:

a. Toxic and Corrosive Fluids: Black letters on a safety-orange background.
b. Flammable Fluids: Black letters on a safety-yellow background.
c. Combustible Fluids: White letters on a safety-brown background.
d. Potable and Other Water: White letters on a safety-green background.
e. Compressed Air: White letters on a safety-blue background.
f. Defined by User: White letters on a safety-purple background, black letters on a safety-white background, white letters on a safety-gray background, and white letters on a safety-black background

3.7 WARNING-TAG INSTALLATION

A. Write required message on, and attach warning tags to, equipment and other items where required.

END OF SECTION 230553

Version 14430

SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Balancing Air Systems:

a. Constant-volume air systems.
b. Dual-duct systems.
c. Variable-air-volume systems.
d. Multizone systems.
e. Induction-unit systems.

2. Balancing Hydronic Piping Systems:

a. Constant-flow hydronic systems.
b. Variable-flow hydronic systems.
c. Primary-secondary hydronic systems.

3. Balancing steam systems.
4. Testing, Adjusting, and Balancing Equipment:

a. Heat exchangers.
b. Motors.
c. Chillers.
d. Cooling towers.
e. Condensing units.
f. Boilers.
g. Heat-transfer coils.

5. Testing, adjusting, and balancing existing systems and equipment.
6. Sound tests.
7. Vibration tests.
8. Duct leakage tests.
9. Control system verification.

1.3 DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

A. AABC: Associated Air Balance Council.

B. BAS: Building automation systems.

C. NEBB: National Environmental Balancing Bureau.

D. TAB: Testing, adjusting, and balancing.

E. TABB: Testing, Adjusting, and Balancing Bureau.

F. TAB Specialist: An independent entity meeting qualifications to perform TAB work.

G. TDH: Total dynamic head.

1.4 PREINSTALLATION MEETINGS

Retain "TAB Conference" Paragraph below if HVAC work is complex enough to justify a conference.

A. TAB Conference: If requested by the Owner, conduct a TAB conference at [**Project site**] <**Insert location**> after approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Provide a minimum of [**14**] <**Insert number**> days' advance notice of scheduled meeting time and location.

1. Minimum Agenda Items:

Coordinate requirements in subparagraphs below with Section 013100 "Project Management and Coordination."

a. The Contract Documents examination report.
b. The TAB plan.
c. Needs for coordination and cooperation of trades and subcontractors.
d. Proposed procedures for documentation and communication flow.

If needed, insert list of conference participants not mentioned in Section 013100 "Project Management and Coordination."

1.5 ACTION SUBMITTALS

A. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for air balancing or HVAC flushing.>

Retain "TAB Report" Subparagraph below to require compliance with ASHRAE 90.1-2013 and ASHRAE 189.1-2013. Submission may be required even if a sustainability scheme is not being implemented, check with authorities having jurisdiction.

2. TAB Report: Documentation indicating that Work complies with ASHRAE/IES 90.1, Section 6.7.2.3 - "System Balancing."

1.6 INFORMATIONAL SUBMITTALS

Coordinate timing of submittals with Section 013200 "Construction Progress Documentation" and Section 013300 "Submittal Procedures."

See Editing Instruction No. 1 in the Evaluations for timing requirements of submittals.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

A. Qualification Data: Within [**30**] [**60**] [**90**] <**Insert number**> days of Contractor's Notice to Proceed, submit documentation that the TAB specialist and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

B. Contract Documents Examination Report: Within [**30**] [**60**] [**90**] <**Insert number**> days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: Within [**30**] [**60**] [**90**] <**Insert number**> days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.

D. System Readiness Checklists: Within [**30**] [**60**] [**90**] <**Insert number**> days of Contractor's Notice to Proceed, submit system readiness checklists as specified in "Preparation" Article.

E. Examination Report: Submit a summary report of the examination review required in "Examination" Article.

F. Certified TAB reports.

Retain first paragraph below for verification purposes unless standard report forms from AABC, NEBB, or TABB are acceptable.

G. Sample report forms.

H. Instrument calibration reports, to include the following:

1. Instrument type and make.
2. Serial number.
3. Application.
4. Dates of use.
5. Dates of calibration.

1.7 QUALITY ASSURANCE

Retain first "TAB Specialists Qualifications" Paragraph below to require an independent contractor for testing and balancing.

A. TAB Specialists Qualifications: Certified by AABC.

1. TAB Field Supervisor: Employee of the TAB specialist and certified by AABC.
2. TAB Technician: Employee of the TAB specialist and certified by AABC as a TAB technician.

Retain "TAB Specialists Qualifications" Paragraph below to require certified contractors.

B. TAB Specialists Qualifications: Certified by [**NEBB**] [**or**] [**TABB**].

1. TAB Field Supervisor: Employee of the TAB specialist and certified by [**NEBB**] [**or**] [**TABB**].
2. TAB Technician: Employee of the TAB specialist and certified by [**NEBB**] [**or**] [**TABB**] as a TAB technician.

C. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."

D. <Double click to insert sustainable design text for air balancing quality assurance requirements.>

Retain "ASHRAE/IES 90.1 Compliance" Paragraph below to require compliance with ASHRAE/IES 90.1-2010 and ASHRAE/IES 90.1-2013 if compliance with ASHRAE 90.1 is independent of any sustainable design requirement.

E. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.7.2.3 - "System Balancing."

1.8 FIELD CONDITIONS

Retain "Full Owner Occupancy" or "Partial Owner Occupancy" Paragraph below. Delete article if there will be no occupancy during TAB work.

A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

Retain "Partial Owner Occupancy" Paragraph below if Owner might occupy completed areas of building.

B. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 TAB SPECIALISTS

Retain this article and list of TAB specialists to limit Contractor's choice of TAB specialists; delete to allow Contractor to select any TAB specialist meeting qualification requirements.

A. Subject to compliance with requirements, [**engage one of the following**] [**available TAB specialists that may be engaged include, but are not limited to, the following**]:

1. <**Insert TAB specialist's name**>.

3.2 EXAMINATION

See "Examination of Contract Documents" Article in the Evaluations for discussion of the Contract Documents review.

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems designs that may preclude proper TAB of systems and equipment.

B. Examine installed systems for balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

See "Design Data" Article in the Evaluations.

D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

F. Examine equipment performance data including fan and pump curves.

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

G. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.

H. Examine test reports specified in individual system and equipment Sections.

I. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.

J. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

K. Examine strainers. Verify that startup screens have been replaced by permanent screens with indicated perforations.

L. Examine control valves for proper installation for their intended function of throttling, diverting, or mixing fluid flows.

M. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

N. Examine system pumps to ensure absence of entrained air in the suction piping.

O. Examine operating safety interlocks and controls on HVAC equipment.

P. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.3 PREPARATION

A. Prepare a TAB plan that includes the following:

1. Equipment and systems to be tested.
2. Strategies and step-by-step procedures for balancing the systems.
3. Instrumentation to be used.
4. Sample forms with specific identification for all equipment.

B. Perform system-readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:

1. Airside:

   a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.
   b. Duct systems are complete with terminals installed.
   c. Volume, smoke, and fire dampers are open and functional.
   d. Clean filters are installed.
   e. Fans are operating, free of vibration, and rotating in correct direction.
   f. Variable-frequency controllers' startup is complete and safeties are verified.
   g. Automatic temperature-control systems are operational.
   h. Ceilings are installed.
   i. Windows and doors are installed.
   j. Suitable access to balancing devices and equipment is provided.

2. Hydronics:

   a. Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.
   b. Piping is complete with terminals installed.
   c. Water treatment is complete.
   d. Systems are flushed, filled, and air purged.
   e. Strainers are pulled and cleaned.
   f. Control valves are functioning per the sequence of operation.
   g. Shutoff and balance valves have been verified to be 100 percent open.
   h. Pumps are started and proper rotation is verified.
   i. Pump gage connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.
   j. Variable-frequency controllers' startup is complete and safeties are verified.
   k. Suitable access to balancing devices and equipment is provided.

3.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

LEED 2009 Prerequisite IEQ 1 "Minimum Energy Performance," LEED v4 Energy and Atmosphere Prerequisite "Minimum Energy Performance," and ASHRAE 189.1 all require compliance with requirements in ASHRAE 62.1-2010, Section 7.2.2 - "Air Balancing." ASHRAE 62.1-2010 requires that ventilation systems be balanced according to ASHRAE 111 or SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing" or be equivalent at least to extent necessary to verify compliance with the standard. The AABC National Standards meet or exceed this requirement.

A. Perform testing and balancing procedures on each system according to the procedures contained in [**AABC's "National Standards for Total System Balance"**] [**ASHRAE 111**] [**NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems"**] [**SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing"**] and in this Section.

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

Retain one of first two subparagraphs below.

1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.
2. After testing and balancing, install test ports and duct access doors that comply with requirements in Section 233300 "Air Duct Accessories."
3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 230713 "Duct Insulation," Section 230716 "HVAC Equipment Insulation," and Section 230719 "HVAC Piping Insulation."

C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.

D. Take and report testing and balancing measurements in [**inch-pound (IP)**] [**and**] [**metric (SI)**] units.

3.5 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Cross-check the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of systems' "as-built" duct layouts.

C. For variable-air-volume systems, develop a plan to simulate diversity.

D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.

E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.

F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

G. Verify that motor starters are equipped with properly sized thermal protection.

H. Check dampers for proper position to achieve desired airflow path.

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

K. Check for proper sealing of air-handling-unit components.

L. Verify that air duct system is sealed as specified in Section 233113 "Metal Ducts."

3.6 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.

    a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
    b. Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses, close to the fan and prior to any outlets, to obtain total airflow.
    c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.

2. Measure fan static pressures as follows:

    a. Measure static pressure directly at the fan outlet or through the flexible connection.
    b. Measure static pressure directly at the fan inlet or through the flexible connection.
    c. Measure static pressure across each component that makes up the air-handling system.
    d. Report artificial loading of filters at the time static pressures are measured.

First two subparagraphs below may require changes to installed systems or equipment; these changes may require a Contract Modification.

3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

See the Evaluations for discussion of fan-speed adjustments.

4. Obtain approval from [**Architect**] [**Owner**] [**Construction Manager**] [**commissioning authority**] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

1. Measure airflow of submain and branch ducts.
2. Adjust submain and branch duct volume dampers for specified airflow.

3. Re-measure each submain and branch duct after all have been adjusted.

C. Adjust air inlets and outlets for each space to indicated airflows.

1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
2. Measure inlets and outlets airflow.
3. Adjust each inlet and outlet for specified airflow.
4. Re-measure each inlet and outlet after they have been adjusted.

D. Verify final system conditions.

1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to design if necessary.
2. Re-measure and confirm that total airflow is within design.
3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
4. Mark all final settings.
5. Test system in economizer mode. Verify proper operation and adjust if necessary.
6. Measure and record all operating data.
7. Record final fan-performance data.

3.7 PROCEDURES FOR DUAL-DUCT SYSTEMS

A. Adjust the dual-duct systems as follows:

1. Verify that the system static pressure sensor is located two-thirds of the distance down the duct from the fan discharge. On systems with separate hot-deck and cold-deck fans, verify the location of the sensor on each deck.
2. Verify that the system is under static pressure control.
3. Select the terminal unit that is most critical to the supply-fan airflow. Measure inlet static pressure, and adjust system static pressure control set point so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
4. Calibrate and balance each terminal unit's hot deck and cold deck for maximum and minimum design airflow as follows:

   a. Adjust controls so that terminal is calling for full cooling. Some controllers require starting with minimum set point. Verify calibration procedure for specific project.
   b. Measure airflow and adjust calibration factors as required for design cold-deck maximum airflow and hot-deck minimum airflow. Record calibration factors.
   c. When maximum airflow is correct, balance the air outlets downstream from terminal units.
   d. Adjust controls so that terminal is calling for full heating.
   e. Measure airflow and adjust calibration factors as required for design cold-deck minimum airflow and hot-deck maximum airflow. Record calibration factors. If no minimum calibration is available, note any deviation from design airflow.

5. After terminals have been calibrated and balanced, test and adjust system for total airflow. Adjust fans to deliver total design airflows within the maximum allowable fan speed listed by fan manufacturer.

a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
b. Set terminals for maximum airflow. If system design includes diversity (cooling coil or fan), adjust terminals for maximum and minimum airflow so that connected total matches cooling coil or fan selection and simulates actual load in the building. In systems with separate hot-deck and cold-deck fans, diversity consideration applies to each individual fan.
c. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
d. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
e. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.

6. Measure the fan(s) static pressures as follows:

a. Measure static pressure directly at the fan outlet or through the flexible connection.
b. Measure static pressure directly at the fan inlet or through the flexible connection.
c. Measure static pressure across each component that makes up the air-handling system.
d. Report any artificial loading of filters at the time static pressures are measured.

7. Set final return and outside airflow to the fan(s) while operating at maximum return airflow and minimum outdoor airflow.

a. Balance the return-air ducts and inlets the same as described for constant-volume air systems.
b. Verify that all terminal units are meeting design airflow under system maximum flow.

8. Re-measure the inlet static pressure at the most critical terminal unit and adjust the system static pressure set point to the most energy-efficient set point to maintain the optimum system static pressure. Record set point and give to controls contractor.
9. Verify final system conditions as follows:

a. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
b. Re-measure and confirm that total airflow is within design.
c. Re-measure final fan operating data, rpms, volts, amps and static profile.
d. Mark final settings.
e. Test system in economizer mode. Verify proper operation and adjust if necessary. Measure and record all operating data.
f. Verify tracking between supply and return fans.

10. Record final fan-performance data.

3.8 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Adjust the variable-air-volume systems as follows:

1. Verify that the system static pressure sensor is located two-thirds of the distance down the duct from the fan discharge.
2. Verify that the system is under static pressure control.
3. Select the terminal unit that is most critical to the supply-fan airflow. Measure inlet static pressure, and adjust system static pressure control set point so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
4. Calibrate and balance each terminal unit for maximum and minimum design airflow as follows:

    a. Adjust controls so that terminal is calling for maximum airflow. Some controllers require starting with minimum airflow. Verify calibration procedure for specific project.
    b. Measure airflow and adjust calibration factor as required for design maximum airflow. Record calibration factor.
    c. When maximum airflow is correct, balance the air outlets downstream from terminal units.
    d. Adjust controls so that terminal is calling for minimum airflow.
    e. Measure airflow and adjust calibration factor as required for design minimum airflow. Record calibration factor. If no minimum calibration is available, note any deviation from design airflow.
    f. When in full cooling or full heating, ensure that there is no mixing of hot-deck and cold-deck airstreams unless so designed.
    g. On constant volume terminals, in critical areas where room pressure is to be maintained, verify that the airflow remains constant over the full range of full cooling to full heating. Note any deviation from design airflow or room pressure.

5. After terminals have been calibrated and balanced, test and adjust system for total airflow. Adjust fans to deliver total design airflows within the maximum allowable fan speed listed by fan manufacturer.

    a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
    b. Set terminals for maximum airflow. If system design includes diversity, adjust terminals for maximum and minimum airflow so that connected total matches fan selection and simulates actual load in the building.
    c. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
    d. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
    e. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.

6. Measure fan static pressures as follows:

    a. Measure static pressure directly at the fan outlet or through the flexible connection.
    b. Measure static pressure directly at the fan inlet or through the flexible connection.
    c. Measure static pressure across each component that makes up the air-handling system.
    d. Report any artificial loading of filters at the time static pressures are measured.

7. Set final return and outside airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

    a. Balance the return-air ducts and inlets the same as described for constant-volume air systems.
    b. Verify that terminal units are meeting design airflow under system maximum flow.

8. Re-measure the inlet static pressure at the most critical terminal unit and adjust the system static pressure set point to the most energy-efficient set point to maintain the optimum system static pressure. Record set point and give to controls contractor.
9. Verify final system conditions as follows:

    a. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
    b. Re-measure and confirm that total airflow is within design.
    c. Re-measure final fan operating data, rpms, volts, amps, and static profile.
    d. Mark final settings.
    e. Test system in economizer mode. Verify proper operation and adjust if necessary. Measure and record all operating data.
    f. Verify tracking between supply and return fans.

3.9 PROCEDURES FOR MULTIZONE SYSTEMS

A. Position the unit's automatic zone dampers for maximum flow through the cooling coil.

B. The procedures for multizone systems will utilize the zone balancing dampers to achieve the indicated airflow within the zone.

C. After balancing, place the unit's automatic zone dampers for maximum heating flow. Retest zone airflows and record any variances.

D. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.

    a. Set outside-air, return-air and relief-air dampers for proper position that simulates minimum outdoor air conditions.
    b. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
    c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
    d. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.

2. Measure fan static pressures as follows:

    a. Measure static pressure directly at the fan outlet or through the flexible connection.
    b. Measure static pressure directly at the fan inlet or through the flexible connection.

c. Measure static pressure across each component that makes up the air-handling system.
d. Report artificial loading of filters at the time static pressures are measured.

First two subparagraphs below may require changes to installed systems or equipment; these changes may require a Contract Modification.

3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

See the Evaluations for discussion of fan-speed adjustments.

4. Obtain approval from [**Architect**] [**Owner**] [**Construction Manager**] [**commissioning authority**] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

E. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

1. Measure airflow of submain and branch ducts.
2. Adjust submain and branch duct volume dampers for specified airflow.
3. Re-measure each submain and branch duct after all have been adjusted.

F. Adjust air inlets and outlets for each space to indicated airflows.

1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
2. Measure inlets and outlets airflow.
3. Adjust each inlet and outlet for specified airflow.
4. Re-measure each inlet and outlet after they have been adjusted.

G. Verify final system conditions.

1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
2. Re-measure and confirm that total airflow is within design.
3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
4. Mark all final settings.
5. Test system in economizer mode. Verify proper operation and adjust if necessary.
6. Measure and record all operating data.
7. Record final fan-performance data.

3.10 PROCEDURES FOR INDUCTION-UNIT SYSTEMS

A. Balance primary-air risers by measuring static pressure at the nozzles of the top and bottom units of each riser to determine which risers must be throttled. Adjust risers to indicated airflow within specified tolerances.

B. Adjust each induction unit.

C. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.

a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
b. Where duct conditions allow, measure airflow by Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses to obtain total airflow.
c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
d. If a reliable Pitot-tube traverse or coil traverse is not possible, measure airflow at terminals and calculate the total airflow.

2. Measure fan static pressures as follows:

a. Measure static pressure directly at the fan outlet or through the flexible connection.
b. Measure static pressure directly at the fan inlet or through the flexible connection.
c. Measure static pressure across each component that makes up the air-handling system.
d. Report artificial loading of filters at the time static pressures are measured.

First two subparagraphs below may require changes to installed systems or equipment; these changes may require a Contract Modification.

3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

See the Evaluations for discussion of fan-speed adjustments.

4. Obtain approval from [**Architect**] [**Owner**] [**Construction Manager**] [**commissioning authority**] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

D. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

1. Measure airflow of submain and branch ducts.
2. Adjust submain and branch duct volume dampers for specified airflow.
3. Re-measure each submain and branch duct after all have been adjusted.

E. Balance airflow to each induction unit by measuring the nozzle pressure and comparing it to the manufacturer's published data for nozzle pressure versus cfm. Adjust the unit's inlet damper to achieve the required nozzle pressure for design cfm.

F. Verify final system conditions.

1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
2. Re-measure and confirm that total airflow is within design.
3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
4. Mark all final settings.
5. Test system in economizer mode. Verify proper operation and adjust if necessary.
6. Measure and record all operating data.
7. Record final fan-performance data.

3.11 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports for pumps, coils, and heat exchangers. Obtain approved submittals and manufacturer-recommended testing procedures. Crosscheck the summation of required coil and heat exchanger flow rates with pump design flow rate.

B. Prepare schematic diagrams of systems' "as-built" piping layouts.

C. In addition to requirements in "Preparation" Article, prepare hydronic systems for testing and balancing as follows:

1. Check liquid level in expansion tank.
2. Check highest vent for adequate pressure.
3. Check flow-control valves for proper position.
4. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
5. Verify that motor starters are equipped with properly sized thermal protection.
6. Check that air has been purged from the system.

3.12 PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

A. Adjust pumps to deliver total design gpm.

1. Measure total water flow.

   a. Position valves for full flow through coils.
   b. Measure flow by main flow meter, if installed.
   c. If main flow meter is not installed, determine flow by pump TDH or exchanger pressure drop.

2. Measure pump TDH as follows:

a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
c. Convert pressure to head and correct for differences in gage heights.
d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
e. With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.

3. Monitor motor performance during procedures and do not operate motor in an overloaded condition.

B. Adjust flow-measuring devices installed in mains and branches to design water flows.

1. Measure flow in main and branch pipes.
2. Adjust main and branch balance valves for design flow.
3. Re-measure each main and branch after all have been adjusted.

C. Adjust flow-measuring devices installed at terminals for each space to design water flows.

1. Measure flow at terminals.
2. Adjust each terminal to design flow.
3. Re-measure each terminal after it is adjusted.
4. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
5. Perform temperature tests after flows have been balanced.

D. For systems with pressure-independent valves at terminals:

1. Measure differential pressure and verify that it is within manufacturer's specified range.
2. Perform temperature tests after flows have been verified.

E. For systems without pressure-independent valves or flow-measuring devices at terminals:

1. Measure and balance coils by either coil pressure drop or temperature method.
2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

F. Verify final system conditions as follows:

1. Re-measure and confirm that total water flow is within design.
2. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.
3. Mark final settings.

G. Verify that memory stops have been set.

3.13 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

A. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals, and proceed as specified above for hydronic systems.

B. Adjust the variable-flow hydronic system as follows:

1. Verify that the differential-pressure sensor is located as indicated.
2. Determine whether there is diversity in the system.

C. For systems with no diversity:

1. Adjust pumps to deliver total design gpm.

a. Measure total water flow.

1) Position valves for full flow through coils.
2) Measure flow by main flow meter, if installed.
3) If main flow meter is not installed, determine flow by pump TDH or exchanger pressure drop.

b. Measure pump TDH as follows:

1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
3) Convert pressure to head and correct for differences in gage heights.
4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
5) With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.

c. Monitor motor performance during procedures and do not operate motor in an overloaded condition.

2. Adjust flow-measuring devices installed in mains and branches to design water flows.

a. Measure flow in main and branch pipes.
b. Adjust main and branch balance valves for design flow.
c. Re-measure each main and branch after all have been adjusted.

3. Adjust flow-measuring devices installed at terminals for each space to design water flows.

a. Measure flow at terminals.
b. Adjust each terminal to design flow.
c. Re-measure each terminal after it is adjusted.

d. Position control valves to bypass the coil and adjust the bypass valve to maintain design flow.
e. Perform temperature tests after flows have been balanced.

4. For systems with pressure-independent valves at terminals:

a. Measure differential pressure and verify that it is within manufacturer's specified range.
b. Perform temperature tests after flows have been verified.

5. For systems without pressure-independent valves or flow-measuring devices at terminals:

a. Measure and balance coils by either coil pressure drop or temperature method.
b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

6. Prior to verifying final system conditions, determine the system differential-pressure set point.
7. If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion open discharge valve 100 percent and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.
8. Mark final settings and verify that all memory stops have been set.
9. Verify final system conditions as follows:

a. Re-measure and confirm that total water flow is within design.
b. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.
c. Mark final settings.

10. Verify that memory stops have been set.

D. For systems with diversity:

1. Determine diversity factor.
2. Simulate system diversity by closing required number of control valves, as approved by the design engineer.
3. Adjust pumps to deliver total design gpm.

a. Measure total water flow.

1) Position valves for full flow through coils.
2) Measure flow by main flow meter, if installed.
3) If main flow meter is not installed, determine flow by pump TDH or exchanger pressure drop.

b. Measure pump TDH as follows:

1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.

3) Convert pressure to head and correct for differences in gage heights.
4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
5) With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.

c. Monitor motor performance during procedures and do not operate motor in an overloaded condition.

4. Adjust flow-measuring devices installed in mains and branches to design water flows.

a. Measure flow in main and branch pipes.
b. Adjust main and branch balance valves for design flow.
c. Re-measure each main and branch after all have been adjusted.

5. Adjust flow-measuring devices installed at terminals for each space to design water flows.

a. Measure flow at terminals.
b. Adjust each terminal to design flow.
c. Re-measure each terminal after it is adjusted.
d. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
e. Perform temperature tests after flows have been balanced.

6. For systems with pressure-independent valves at terminals:

a. Measure differential pressure, and verify that it is within manufacturer's specified range.
b. Perform temperature tests after flows have been verified.

7. For systems without pressure-independent valves or flow-measuring devices at terminals:

a. Measure and balance coils by either coil pressure drop or temperature method.
b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

8. Open control valves that were shut. Close a sufficient number of control valves that were previously open to maintain diversity, and balance terminals that were just opened.
9. Prior to verifying final system conditions, determine system differential-pressure set point.
10. If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion open discharge valve 100 percent and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.
11. Mark final settings and verify that memory stops have been set.
12. Verify final system conditions as follows:

a. Re-measure and confirm that total water flow is within design.
b. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.

c. Mark final settings.

13. Verify that memory stops have been set.

3.14 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

A. Balance the primary circuit flow first.

B. Balance the secondary circuits after the primary circuits are complete.

C. Adjust pumps to deliver total design gpm.

1. Measure total water flow.

    a. Position valves for full flow through coils.
    b. Measure flow by main flow meter, if installed.
    c. If main flow meter is not installed, determine flow by pump TDH or exchanger pressure drop.

2. Measure pump TDH as follows:

    a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
    b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
    c. Convert pressure to head and correct for differences in gage heights.
    d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
    e. With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.

3. Monitor motor performance during procedures and do not operate motor in an overloaded condition.

D. Adjust flow-measuring devices installed in mains and branches to design water flows.

1. Measure flow in main and branch pipes.
2. Adjust main and branch balance valves for design flow.
3. Re-measure each main and branch after all have been adjusted.

E. Adjust flow-measuring devices installed at terminals for each space to design water flows.

1. Measure flow at terminals.
2. Adjust each terminal to design flow.
3. Re-measure each terminal after it is adjusted.
4. Position control valves to bypass the coil and adjust the bypass valve to maintain design flow.
5. Perform temperature tests after flows have been balanced.

F. For systems with pressure-independent valves at terminals:

1. Measure differential pressure and verify that it is within manufacturer's specified range.
2. Perform temperature tests after flows have been verified.

G. For systems without pressure-independent valves or flow-measuring devices at terminals:

1. Measure and balance coils by either coil pressure drop or temperature method.
2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

H. Verify final system conditions as follows:

1. Re-measure and confirm that total water flow is within design.
2. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.
3. Mark final settings.

I. Verify that memory stops have been set.

3.15 PROCEDURES FOR STEAM SYSTEMS

A. Measure and record upstream and downstream pressure of each piece of equipment.

B. Measure and record upstream and downstream steam pressure of pressure-reducing valves.

C. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.

D. Check settings and operation of each safety valve. Record settings.

E. Verify the operation of each steam trap.

3.16 PROCEDURES FOR HEAT EXCHANGERS

A. Adjust water flow to within specified tolerances.

B. Measure inlet and outlet water temperatures.

C. Measure inlet steam pressure.

D. Check settings and operation of safety and relief valves. Record settings.

3.17 PROCEDURES FOR MOTORS

Retain this article if using motors.

A. Motors 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer's name, model number, and serial number.
2. Motor horsepower rating.
3. Motor rpm.

4. Phase and hertz.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter size and thermal-protection-element rating.
8. Service factor and frame size.

B. Motors Driven by Variable-Frequency Controllers: Test manual bypass of controller to prove proper operation.

3.18 PROCEDURES FOR CHILLERS

A. Balance water flow through each evaporator[**and condenser**] to within specified tolerances of indicated flow with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
2. For water-cooled chillers, condenser-water entering and leaving temperatures, pressure drop, and water flow.
3. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
4. Power factor if factory-installed instrumentation is furnished for measuring kilowatts.
5. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
6. Capacity: Calculate in tons of cooling.
7. For air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

3.19 PROCEDURES FOR COOLING TOWERS

Tests in paragraph below do not comply with CTI STD-105, "Acceptance Test Code."

A. Balance total condenser-water flows to towers. Measure and record the following data:

1. Condenser-water flow to each cell of the cooling tower.
2. Entering- and leaving-water temperatures.
3. Wet- and dry-bulb temperatures of entering air.
4. Wet- and dry-bulb temperatures of leaving air.
5. Condenser-water flow rate recirculating through the cooling tower.
6. Cooling-tower spray pump discharge pressure.
7. Condenser-water flow through bypass.
8. Fan and motor operating data.

3.20 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record fan and motor operating data.

3.21 PROCEDURES FOR BOILERS

A. Hydronic Boilers:

1. Measure and record entering- and leaving-water temperatures.
2. Measure and record water flow.
3. Record relief valve pressure setting.

B. Steam Boilers:

1. Measure and record entering-water temperature.
2. Measure and record feed water flow.
3. Measure and record leaving-steam pressure and temperature.
4. Record relief valve pressure setting.

3.22 PROCEDURES FOR HEAT-TRANSFER COILS

A. Measure, adjust, and record the following data for each water coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop for major (more than 20 gpm) equipment coils, excluding unitary equipment such as reheat coils, unit heaters, and fan-coil units.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.

B. Measure, adjust, and record the following data for each electric heating coil:

1. Nameplate data.
2. Airflow.
3. Entering- and leaving-air temperature at full load.
4. Voltage and amperage input of each phase at full load.
5. Calculated kilowatt at full load.
6. Fuse or circuit-breaker rating for overload protection.

C. Measure, adjust, and record the following data for each steam coil:

1. Dry-bulb temperature of entering and leaving air.
2. Airflow.
3. Inlet steam pressure.

D. Measure, adjust, and record the following data for each refrigerant coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.

3.23 SOUND TESTS

A. After the systems are balanced and construction is Substantially Complete, measure and record sound levels at [**5**] [**10**] [**15**] <**Insert number**> locations as designated by the Architect.

B. Instrumentation:

1. The sound-testing meter shall be a portable, general-purpose testing meter consisting of a microphone, processing unit, and readout.
2. The sound-testing meter shall be capable of showing fluctuations at minimum and maximum levels, and measuring the equivalent continuous sound pressure level (LEQ).
3. The sound-testing meter must be capable of using 1/3 octave band filters to measure mid-frequencies from 31.5 Hz to 8000 Hz.
4. The accuracy of the sound-testing meter shall be plus or minus one decibel.

C. Test Procedures:

1. Perform test at quietest background noise period. Note cause of unpreventable sound that affects test outcome.
2. Equipment should be operating at design values.
3. Calibrate the sound-testing meter prior to taking measurements.
4. Use a microphone suitable for the type of noise levels measured that is compatible with meter. Provide a windshield for outside or in-duct measurements.
5. Record a set of background measurements in dBA and sound pressure levels in the eight un-weighted octave bands [**63 Hz to 8000 Hz (NC)**] [**31.5 Hz to 4000 Hz (RC)**] with the equipment off.
6. Take sound readings in dBA and sound pressure levels in the eight un-weighted octave bands [**63 Hz to 8000 Hz (NC)**] [**31.5 Hz to 4000 Hz (RC)**] with the equipment operating.
7. Take readings no closer than 36 inches from a wall or from the operating equipment and approximately 60 inches from the floor, with the meter held or mounted on a tripod.
8. For outdoor measurements, move sound-testing meter slowly and scan area that has the most exposure to noise source being tested. Use A-weighted scale for this type of reading.

D. Reporting:

1. Report shall record the following:
   a. Location.
   b. System tested.
   c. dBA reading.
   d. Sound pressure level in each octave band with equipment on and off.
2. Plot sound pressure levels on [**NC**] [**RC**] worksheet with equipment on and off.

3.24 VIBRATION TESTS

A. After systems are balanced and construction is Substantially Complete, measure and record vibration levels on equipment having motor horsepower equal to or greater than [**10**] [**15**] [**25**]<**Insert number**>.

B. Instrumentation:

1. Use portable, battery-operated, and microprocessor-controlled vibration meter with or without a built-in printer.
2. The meter shall automatically identify engineering units, filter bandwidth, amplitude, and frequency scale values.
3. The meter shall be able to measure machine vibration displacement in mils of deflection, velocity in inches per second, and acceleration in inches per second squared.
4. Verify calibration date is current for vibration meter before taking readings.

C. Test Procedures:

1. To ensure accurate readings, verify that accelerometer has a clean, flat surface and is mounted properly.
2. With the unit running, set up vibration meter in a safe, secure location. Connect transducer to meter with proper cables. Hold magnetic tip of transducer on top of the bearing, and measure unit in mils of deflection. Record measurement, then move transducer to the side of the bearing and record in mils of deflection. Record an axial reading in mils of deflection by holding nonmagnetic, pointed transducer tip on end of shaft.
3. Change vibration meter to velocity (inches per second) measurements. Repeat and record above measurements.
4. Record CPM or rpm.
5. Read each bearing on motor, fan, and pump as required. Track and record vibration levels from rotating component through casing to base.

D. Reporting:

1. Report shall record location and the system tested.
2. Include horizontal-vertical-axial measurements for tests.
3. Verify that vibration limits follow Specifications, or, if not specified, follow the General Machinery Vibration Severity Chart or Vibration Acceleration General Severity Chart from the AABC National Standards. Acceptable levels of vibration are normally "smooth" to "good."
4. Include in report General Machinery Vibration Severity Chart, with conditions plotted.

3.25 DUCT LEAKAGE TESTS

A. Witness the duct pressure testing performed by Installer.

B. Verify that proper test methods are used and that leakage rates are within specified tolerances.

C. Report deficiencies observed.

3.26 CONTROLS VERIFICATION

A. In conjunction with system balancing, perform the following:

1. Verify temperature control system is operating within the design limitations.
2. Confirm that the sequences of operation are in compliance with Contract Documents.
3. Verify that controllers are calibrated and function as intended.
4. Verify that controller set points are as indicated.
5. Verify the operation of lockout or interlock systems.
6. Verify the operation of valve and damper actuators.
7. Verify that controlled devices are properly installed and connected to correct controller.
8. Verify that controlled devices travel freely and are in position indicated by controller: open, closed, or modulating.
9. Verify location and installation of sensors to ensure that they sense only intended temperature, humidity, or pressure.

B. Reporting: Include a summary of verifications performed, remaining deficiencies, and variations from indicated conditions.

3.27 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

A. Perform a preconstruction inspection of existing equipment that is to remain and be reused.

1. Measure and record the operating speed, airflow, and static pressure of each fan.
2. Measure motor voltage and amperage. Compare the values to motor nameplate information.
3. Check the refrigerant charge.
4. Check the condition of filters.
5. Check the condition of coils.
6. Check the operation of the drain pan and condensate-drain trap.
7. Check bearings and other lubricated parts for proper lubrication.
8. Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.

B. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished. Verify the following:

1. New filters are installed.
2. Coils are clean and fins combed.
3. Drain pans are clean.
4. Fans are clean.
5. Bearings and other parts are properly lubricated.
6. Deficiencies noted in the preconstruction report are corrected.

C. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.

1. Compare the indicated airflow of the renovated work to the measured fan airflows, and determine the new fan speed and the face velocity of filters and coils.

2. Verify that the indicated airflows of the renovated work result in filter and coil face velocities and fan speeds that are within the acceptable limits defined by equipment manufacturer.
3. If calculations increase or decrease the airflow rates and water flow rates by more than 5 percent, make equipment adjustments to achieve the calculated rates. If increase or decrease is 5 percent or less, equipment adjustments are not required.
4. Balance each air outlet.

3.28 TOLERANCES

A. Set HVAC system's airflow rates and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: [**Plus or minus 10 percent**] <**Insert value**>.
2. Air Outlets and Inlets: [**Plus or minus 10 percent**] <**Insert value**>.
3. Heating-Water Flow Rate: [**Plus or minus 10 percent**] <**Insert value**>.
4. Cooling-Water Flow Rate: [**Plus or minus 10 percent**] <**Insert value**>.

B. Maintaining pressure relationships as designed shall have priority over the tolerances specified above.

3.29 PROGRESS REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems balancing devices. Recommend changes and additions to systems balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: Prepare [**weekly**] [**biweekly**] [**monthly**] <**Insert time interval**> progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.30 FINAL REPORT

Revise contents of reports specified in this article to suit office practice.

A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.
3. Certify validity and accuracy of field data.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance; do not include Shop Drawings and Product Data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB specialist.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:

    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.

12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans and pump performance forms including the following:

    a. Settings for outdoor-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Face and bypass damper settings at coils.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.
    f. Inlet vane settings for variable-air-volume systems.
    g. Settings for supply-air, static-pressure controller.
    h. Other system operating conditions that affect performance.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outdoor, supply, return, and exhaust airflows.
2. Water and steam flow rates.
3. Duct, outlet, and inlet sizes.
4. Pipe and valve sizes and locations.
5. Terminal units.
6. Balancing stations.
7. Position of balancing devices.

E. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Make and type.
d. Model number and unit size.
e. Manufacturer's serial number.
f. Unit arrangement and class.
g. Discharge arrangement.
h. Sheave make, size in inches, and bore.
i. Center-to-center dimensions of sheave and amount of adjustments in inches.
j. Number, make, and size of belts.
k. Number, type, and size of filters.

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Center-to-center dimensions of sheave and amount of adjustments in inches.

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Filter static-pressure differential in inches wg.
f. Preheat-coil static-pressure differential in inches wg.
g. Cooling-coil static-pressure differential in inches wg.
h. Heating-coil static-pressure differential in inches wg.
i. Outdoor airflow in cfm.
j. Return airflow in cfm.
k. Outdoor-air damper position.
l. Return-air damper position.
m. Vortex damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:

a. System identification.
b. Location.
c. Coil type.
d. Number of rows.
e. Fin spacing in fins per inch o.c.
f. Make and model number.

g. Face area in sq. ft..
h. Tube size in NPS.
i. Tube and fin materials.
j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Average face velocity in fpm.
c. Air pressure drop in inches wg.
d. Outdoor-air, wet- and dry-bulb temperatures in deg F.
e. Return-air, wet- and dry-bulb temperatures in deg F.
f. Entering-air, wet- and dry-bulb temperatures in deg F.
g. Leaving-air, wet- and dry-bulb temperatures in deg F.
h. Water flow rate in gpm.
i. Water pressure differential in feet of head or psig.
j. Entering-water temperature in deg F.
k. Leaving-water temperature in deg F.
l. Refrigerant expansion valve and refrigerant types.
m. Refrigerant suction pressure in psig.
n. Refrigerant suction temperature in deg F.
o. Inlet steam pressure in psig.

G. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:

1. Unit Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and unit size.
e. Manufacturer's serial number.
f. Fuel type in input data.
g. Output capacity in Btu/h.
h. Ignition type.
i. Burner-control types.
j. Motor horsepower and rpm.
k. Motor volts, phase, and hertz.
l. Motor full-load amperage and service factor.
m. Sheave make, size in inches, and bore.
n. Center-to-center dimensions of sheave and amount of adjustments in inches.

2. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm.
b. Entering-air temperature in deg F.
c. Leaving-air temperature in deg F.
d. Air temperature differential in deg F.
e. Entering-air static pressure in inches wg.
f. Leaving-air static pressure in inches wg.

g. Air static-pressure differential in inches wg.
h. Low-fire fuel input in Btu/h.
i. High-fire fuel input in Btu/h.
j. Manifold pressure in psig.
k. High-temperature-limit setting in deg F.
l. Operating set point in Btu/h.
m. Motor voltage at each connection.
n. Motor amperage for each phase.
o. Heating value of fuel in Btu/h.

H. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:

1. Unit Data:

a. System identification.
b. Location.
c. Coil identification.
d. Capacity in Btu/h.
e. Number of stages.
f. Connected volts, phase, and hertz.
g. Rated amperage.
h. Airflow rate in cfm.
i. Face area in sq. ft..
j. Minimum face velocity in fpm.

2. Test Data (Indicated and Actual Values):

a. Heat output in Btu/h.
b. Airflow rate in cfm.
c. Air velocity in fpm.
d. Entering-air temperature in deg F.
e. Leaving-air temperature in deg F.
f. Voltage at each connection.
g. Amperage for each phase.

I. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches, and bore.
h. Center-to-center dimensions of sheave and amount of adjustments in inches.

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Center-to-center dimensions of sheave, and amount of adjustments in inches.
g. Number, make, and size of belts.

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Suction static pressure in inches wg.

J. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

a. System and air-handling-unit number.
b. Location and zone.
c. Traverse air temperature in deg F.
d. Duct static pressure in inches wg.
e. Duct size in inches.
f. Duct area in sq. ft..
g. Indicated airflow rate in cfm.
h. Indicated velocity in fpm.
i. Actual airflow rate in cfm.
j. Actual average velocity in fpm.
k. Barometric pressure in psig.

K. Air-Terminal-Device Reports:

1. Unit Data:

a. System and air-handling unit identification.
b. Location and zone.
c. Apparatus used for test.
d. Area served.
e. Make.
f. Number from system diagram.
g. Type and model number.
h. Size.
i. Effective area in sq. ft..

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Air velocity in fpm.

c. Preliminary airflow rate as needed in cfm.
d. Preliminary velocity as needed in fpm.
e. Final airflow rate in cfm.
f. Final velocity in fpm.
g. Space temperature in deg F.

L. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

a. System and air-handling-unit identification.
b. Location and zone.
c. Room or riser served.
d. Coil make and size.
e. Flowmeter type.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Entering-water temperature in deg F.
c. Leaving-water temperature in deg F.
d. Water pressure drop in feet of head or psig.
e. Entering-air temperature in deg F.
f. Leaving-air temperature in deg F.

Net positive suction head is important for pumps in open circuits and for pumps handling fluids at elevated temperatures.

M. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Service.
d. Make and size.
e. Model number and serial number.
f. Water flow rate in gpm.
g. Water pressure differential in feet of head or psig.
h. Required net positive suction head in feet of head or psig.
i. Pump rpm.
j. Impeller diameter in inches.
k. Motor make and frame size.
l. Motor horsepower and rpm.
m. Voltage at each connection.
n. Amperage for each phase.
o. Full-load amperage and service factor.
p. Seal type.

2. Test Data (Indicated and Actual Values):

a. Static head in feet of head or psig.
b. Pump shutoff pressure in feet of head or psig.
c. Actual impeller size in inches.
d. Full-open flow rate in gpm.
e. Full-open pressure in feet of head or psig.
f. Final discharge pressure in feet of head or psig.
g. Final suction pressure in feet of head or psig.
h. Final total pressure in feet of head or psig.
i. Final water flow rate in gpm.
j. Voltage at each connection.
k. Amperage for each phase.

N. Instrument Calibration Reports:

1. Report Data:

a. Instrument type and make.
b. Serial number.
c. Application.
d. Dates of use.
e. Dates of calibration.

3.31 VERIFICATION OF TAB REPORT

A. The TAB specialist's test and balance engineer shall conduct the inspection in the presence of [**Architect**] [**Owner**] [**Construction Manager**] [**commissioning authority**].

B. [**Architect**] [**Owner**] [**Construction Manager**] [**Commissioning authority**] shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.

C. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."

D. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

E. If TAB work fails, proceed as follows:

1. TAB specialists shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
2. If the second final inspection also fails, Owner may contract the services of another TAB specialist to complete TAB work according to the Contract Documents and deduct the cost of the services from the original TAB specialist's final payment.

Retain subparagraph below if TAB specialist is a certified AABC specialist.

3. If the second verification also fails, [**Owner**] [**design professional**] [**Architect**] may contact AABC Headquarters regarding the AABC National Performance Guaranty.

F. Prepare test and inspection reports.

3.32 ADDITIONAL TESTS

A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 230593

SECTION 230713 - DUCT INSULATION

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer's products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes insulating the following duct services:

The list below matches the various systems in the schedule articles. Coordinate the revision of list with "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," and "Aboveground, Outdoor Duct and Plenum Insulation Schedule" articles.

1. Indoor, concealed supply and outdoor air.
2. Indoor, exposed supply and outdoor air.
3. Indoor, concealed return located in unconditioned space.
4. Indoor, exposed return located in unconditioned space.
5. Indoor, concealed, Type I, commercial, kitchen hood exhaust.
6. Indoor, exposed, Type I, commercial, kitchen hood exhaust.
7. Indoor, concealed oven and warewash exhaust.
8. Indoor, exposed oven and warewash exhaust.
9. Indoor, concealed exhaust between isolation damper and penetration of building exterior.
10. Indoor, exposed exhaust between isolation damper and penetration of building exterior.
11. Outdoor, concealed supply and return.
12. Outdoor, exposed supply and return.

B. Related Sections:

Retain Sections in subparagraphs below that contain requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 230716 "HVAC Equipment Insulation."
2. Section 230719 "HVAC Piping Insulation."
3. Section 233113 "Metal Ducts" for duct liners.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied if any).

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for adhesives.>
2. <Double click to insert sustainable design text for coatings.>
3. <Double click to insert sustainable design text for sealants.>

C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
2. Detail insulation application at elbows, fittings, dampers, specialties and flanges for each type of insulation.
3. Detail application of field-applied jackets.
4. Detail application at linkages of control devices.

Retain first paragraph below to verify products with Samples.

D. Samples: For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use. Sample sizes are as follows:

1. Sheet Form Insulation Materials: 12 inches square.
2. Sheet Jacket Materials: 12 inches square.

3. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.4 INFORMATIONAL SUBMITTALS

Coordinate first paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

A. Qualification Data: For qualified Installer.

Retain first paragraph below if surface-burning characteristics specified in "Quality Assurance" Article are specified to be verified by an independent testing agency.

B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.

Retain paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

1.5 QUALITY ASSURANCE

Retain first paragraph below if available at Project location. Apprenticeship programs are usually associated with union shops. Other craft training programs are available.

A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.

When fire-performance characteristics are important requirements, verify surface-burning characteristics of insulation materials by an independent testing agency and require test report submittals.

B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

If retaining "Mockups" Paragraph below, indicate location, size, and other details of mockups on Drawings or by inserts. Revise if only one mockup is required.

C. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by Architect. Use materials indicated for the completed Work.

1. Ductwork Mockups:

    a. One 10-foot section each of rectangular and round straight duct.
    b. One each of a 90-degree mitered round and rectangular elbow, and one each of a 90-degree radius round and rectangular elbow.
    c. One rectangular branch takeoff and one round branch takeoff from a rectangular duct. One round tee fitting.
    d. One rectangular and round transition fitting.
    e. Four support hangers for round and rectangular ductwork.
    f. Each type of damper and specialty.

2. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
3. Notify Architect seven days in advance of dates and times when mockups will be constructed.
4. Obtain Architect's approval of mockups before starting insulation application.

Retain first subparagraph below if mockups are not only for establishing appearance factors.

5. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
6. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
7. Demolish and remove mockups when directed.

1.6 DELIVERY, STORAGE, AND HANDLING

Retain this article to require shipping container markings. Container marking is an option in ASTM standards; default condition does not include the marking in this article unless specified in the Contract.

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.7 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with duct Installer for duct insulation application. Before preparing ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate installation and testing of heat tracing.

1.8 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

If retaining more than one type of insulation in this article, indicate where each type applies in insulation system schedules.

A. Comply with requirements in "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," and "Aboveground, Outdoor Duct and Plenum Insulation Schedule" articles for where insulating materials shall be applied.

See "Product Characteristics" Article in the Evaluations for comparisons and temperature ranges for insulation material properties.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

"Flexible Elastomeric Insulation" Paragraph below is unsuitable for temperatures lower than minus 70 deg F (minus 57 deg C) and higher than 220 deg F (104 deg C).

F. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C534, Type II for sheet materials.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Aeroflex USA.
b. Armacell LLC.

For operating temperatures higher than 250 deg F (121 deg C), use blanket insulation in first paragraph below. Retain ASTM C1290 types as follows: Type I for insulation without jackets, Type II for insulation with vinyl jackets, and Type III for insulation with FSK or FSP jackets.

G. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C553, Type II and ASTM C1290, [**Type I**] [**Type II with factory-applied vinyl jacket**] [**Type III with factory-applied FSK jacket**] [**Type III with factory-applied FSP jacket**]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. CertainTeed Corporation.
   b. Johns Manville; a Berkshire Hathaway company.
   c. Knauf Insulation.
   d. Manson Insulation Inc.

For operating temperatures higher than 250 deg F (121 deg C), use board insulation in first paragraph below. The most common jacket for ductwork and plenum applications is FSK.

H. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C612, Type IA or Type IB. For duct and plenum applications, provide insulation [**without factory-applied jacket**] [**with factory-applied ASJ**] [**with factory-applied FSK jacket**]. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. CertainTeed Corporation.
   b. Johns Manville; a Berkshire Hathaway company.
   c. Knauf Insulation.
   d. Manson Insulation Inc.

Pipe and tank insulation is used for large-diameter piping and vessels. ASJ is commonly used.

I. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied [**ASJ**] [**FSK jacket**] complying with ASTM C1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 100 deg F is 0.29 Btu x in./h x sq. ft. x deg F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers**

offering products that may be incorporated into the Work include, but are not limited to, the following]:

a. CertainTeed Corporation.
b. Johns Manville; a Berkshire Hathaway company.
c. Knauf Insulation.
d. Manson Insulation Inc.

J. Polyolefin: Unicellular, polyethylene thermal plastic insulation. Comply with ASTM C534 or ASTM C1427, Type I, Grade 1 for tubular materials and Type II, Grade 1 for sheet materials.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. <**Insert manufacturer's name**>.

2.2 FIRE-RATED INSULATION SYSTEMS

Retain this article for fire-rated insulation, which is sometimes used in lieu of fire-rated assemblies. A common application is for Type I, commercial, kitchen hood exhaust ductwork. See Evaluations.

A. Fire-Rated Board: Structural-grade, press-molded, xonolite calcium silicate, fireproofing board suitable for operating temperatures up to 1700 deg F. Comply with ASTM C656, Type II, Grade 6. Tested and certified to provide a [**1**] [**2**]-hour fire rating by an NRTL acceptable to authorities having jurisdiction.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. <**Insert manufacturer's name**>.

B. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with FSK jacket that is tested and certified to provide a [**1**] [**2**]-hour fire rating by an NRTL acceptable to authorities having jurisdiction.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. 3M.
b. CertainTeed Corporation.
c. Johns Manville; a Berkshire Hathaway company.
d. Nelson Firestop; a brand of Emerson Industrial Automation.
e. Thermal Ceramics.

2.3 ADHESIVES

Military Specification in this article was the only standard available when this Section was written. MIL-A-3316C was last updated in October 1987.

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

Product attributes in first paragraph below are based on Foster Brand products; there are variations among manufacturers.

B. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. Aeroflex USA.
   b. Armacell LLC.
   c. Foster Brand; H. B. Fuller Construction Products.

2. <Double click to insert sustainable design text for VOC content of plastic foam adhesive.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

C. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. Childers Brand; H. B. Fuller Construction Products.
   b. Eagle Bridges - Marathon Industries.
   c. Foster Brand; H. B. Fuller Construction Products.

2. <Double click to insert sustainable design text for fiberglass pipe adhesive.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

D. ASJ Adhesive, and FSK Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Childers Brand; H. B. Fuller Construction Products.
   b. Eagle Bridges - Marathon Industries.
   c. Foster Brand; H. B. Fuller Construction Products.

2. <Double click to insert sustainable design text for adhesive.>

3. <Double click to insert sustainable design text for low emitting adhesives.>

E. PVC Jacket Adhesive: Compatible with PVC jacket.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Johns Manville; a Berkshire Hathaway company.
b. P.I.C. Plastics, Inc.
c. Speedline Corporation.

2. <Double click to insert sustainable design text for adhesive.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

2.4 MASTICS AND COATINGS

Mastic and coating terminology is used interchangeably in this article. Manufacturers refer to vapor barrier formulations and vapor-retarder formulations as "mastics" or "coatings." Low-permeance mastics and coatings are termed "vapor retarders." Products with a perm rating of greater than 1.0 are called "breathable." Consider ambient conditions and operating temperatures when selecting mastics and coatings. Consider using water-based mastics and coatings for environmental reasons.

LEED 2009 IEQ Credit 4.1 does not address requirements for mastics and coatings. LEED 2009 IEQ Credit 4.2 does address requirements for mastics and coatings. LEED v4 EQ Credit "Low-Emitting Materials" does address requirements for mastics and coatings.

A. Materials shall be compatible with insulation materials, jackets, and substrates.

1. <Double click to insert sustainable design text for mastic coatings.>

Verify that products listed comply with water-vapor permeance. Require proof of performance and certified test reports from vapor-barrier mastic manufacturer to support product literature claims.

Retain one of four paragraphs below. Consider insulation type and operating conditions when selecting mastics and coatings.

B. Vapor-Retarder Mastic: Water based; suitable for indoor use on below ambient services.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Childers Brand; H. B. Fuller Construction Products.
b. Foster Brand; H. B. Fuller Construction Products.
c. Knauf Insulation.

2. Water-Vapor Permeance: Comply with ASTM C755, Section 7.2.2, Table 2, for insulation type and service conditions.
3. Service Temperature Range: Minus 20 to plus 180 deg F.

Retain MIL-PRF-19565C in first subparagraph below for vapor-retarder mastics and coatings if applicable to project.

4. Comply with MIL-PRF-19565C, Type II, for permeance requirements[**, with supplier listing on DOD QPD - Qualified Products Database**].
5. Color: [**White**] <**Insert color**>.

Retain solvent-based "Vapor-Retarder Mastic" Paragraph below if low-VOC mastics and coatings are not required, or if a lower permeance is required.

C. Vapor-Retarder Mastic: Solvent based; suitable for indoor use on below ambient services.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Childers Brand; H. B. Fuller Construction Products.
    b. Eagle Bridges - Marathon Industries.
    c. Foster Brand; H. B. Fuller Construction Products.

2. Water-Vapor Permeance: Comply with ASTM C755, Section 7.2.2, Table 2, for insulation type and service conditions.
3. Service Temperature Range: 0 to 180 deg F.
4. Color: [**White**] <**Insert color**>.

D. Vapor-Retarder Mastic: Solvent based; suitable for outdoor use on below ambient services.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Childers Brand; H. B. Fuller Construction Products.
    b. Eagle Bridges - Marathon Industries.

2. Water-Vapor Permeance: Comply with ASTM C755, Section 7.2.2, Table 2, for insulation type and service conditions.
3. Service Temperature Range: Minus 50 to plus 220 deg F.
4. Color: [**White**] <**Insert color**>.

E. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Childers Brand; H. B. Fuller Construction Products.
    b. Eagle Bridges - Marathon Industries.
    c. Foster Brand; H. B. Fuller Construction Products.
    d. Knauf Insulation.
    e. Mon-Eco Industries, Inc.

2. Water-Vapor Permeance: ASTM E96, greater than 1.0 perm at manufacturer's recommended dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Color: [**White**] <**Insert color**>.

2.5 LAGGING ADHESIVES

A. Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Childers Brand; H. B. Fuller Construction Products.
b. Foster Brand; H. B. Fuller Construction Products.

2. <Double click to insert sustainable design text for VOC content of adhesive.>
3. <Double click to insert sustainable design text for low emitting adhesives.>
4. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over duct insulation.
5. Service Temperature Range: 0 to plus 180 deg F.
6. Color: White.

2.6 SEALANTS

Materials in first paragraph below are for sealing metal jacket seams and joints.

A. FSK and Metal Jacket Flashing Sealants:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Childers Brand; H. B. Fuller Construction Products.
b. Eagle Bridges - Marathon Industries.
c. Foster Brand; H. B. Fuller Construction Products.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: Aluminum.
6. <Double click to insert sustainable design text for sealant.>
7. <Double click to insert sustainable design text for sealants.>

B. ASJ Flashing Sealants, and Vinyl and PVC Jacket Flashing Sealants:

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. <**Insert manufacturer's name**>.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.

5. Color: White.
6. <Double click to insert sustainable design text for sealant.>
7. <Double click to insert sustainable design text for sealants.>

2.7 FACTORY-APPLIED JACKETS

Coordinate types of factory-applied jacket insulation materials selected and types of factory-applied jackets indicated in insulation system schedules.

For insulation materials with factory-applied jackets for use on applications above 140 deg F (60 deg C), specify sufficient insulation thickness to maintain outer surface temperature of insulation below 140 deg F (60 deg C). 140 deg F (60 deg C) surface temperature is set by OSHA for personnel protection.

Knauf is the only mineral-fiber insulation manufacturer that offers factory-applied FSP jacket for blanket insulation. CertainTeed and Johns Manville offer a vinyl jacket, but it does not comply with ASTM C1136. Owens Corning does not offer an FSP or a vinyl product.

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C1136, Type II.
4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C1136, Type II.
5. Vinyl Jacket: White vinyl with a permeance of 1.3 perms when tested according to ASTM E96/E96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.8 FIELD-APPLIED FABRIC-REINFORCING MESH

Both glass-fiber- and polyester-fabric-reinforcing meshes are acceptable.

Retain both paragraphs below to give Contractor option to use either glass-fiber or polyester fabric.

A. Woven Glass-Fiber Fabric: Approximately 6 oz./sq. yd. with a thread count of 5 strands by 5 strands/sq. in. for covering ducts.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. <**Insert manufacturer's name**>.

B. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in., in a Leno weave, for ducts.

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

    a. Foster Brand; H. B. Fuller Construction Products.

2.9 FIELD-APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd..

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. <**Insert manufacturer's name**>.

2.10 FIELD-APPLIED JACKETS

Insulation jackets in this article are for field application. ASTM C921, Type I, is for use over insulation on ducts operating at below ambient temperatures at least part of the time or where a vapor barrier is required. ASTM C921, Type II, is for use over insulation on ducts operating above ambient temperatures or where a vapor retarder is not required.

A. Field-applied jackets shall comply with ASTM C921, Type I, unless otherwise indicated.

A properly sealed FSK jacket, common with most forms of factory-applied jackets for mineral-fiber insulation, complies with vapor-retarder requirements in ASTM C921, Type I.

B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

Although other thicknesses for PVC jackets are available, a flame-spread index of 25 and a smoke-developed index of 50 apply only to thicknesses of 30 mils (0.8 mm) and less.

C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Johns Manville; a Berkshire Hathaway company.
    b. P.I.C. Plastics, Inc.
    c. Proto Corporation.

2. Adhesive: As recommended by jacket material manufacturer.

PVC jackets are available in several colors. Colored jackets may be used to replace field painting. UV rays fade colors in exterior applications. Some colors (black, gray, and white) do not fade as quickly as other colors (red, orange, and green). Colored jackets have different emissivity and are not recommended for outdoor use.

3. Color: [**White**] [**Color-code jackets based on system. Color as selected by Architect**].

D. Metal Jacket:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

a. ITW Insulation Systems; Illinois Tool Works, Inc.

2. Aluminum Jacket: Comply with ASTM B209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.

a. [**Sheet and roll stock ready for shop or field sizing**] [**Factory cut and rolled to size**].
b. Finish and thickness are indicated in field-applied jacket schedules.

Among the three moisture barriers in first subparagraph below, 1-mil (0.025-mm) barrier provides the least protection against galvanic corrosion, 3-mil (0.075-mm) barrier offers better protection, and polysurlyn barrier offers the best protection. For most indoor applications, 1-mil (0.025-mm) barrier is adequate. For outdoor applications, select either 3-mil (0.075-mm) or polysurlyn barrier.

c. Moisture Barrier for Indoor Applications: [**1-mil-thick, heat-bonded polyethylene and kraft paper**] [**3-mil-thick, heat-bonded polyethylene and kraft paper**] [**2.5-mil-thick polysurlyn**].
d. Moisture Barrier for Outdoor Applications: [**3-mil-thick, heat-bonded polyethylene and kraft paper**] [**2.5-mil-thick polysurlyn**].

3. Stainless-Steel Jacket: ASTM A167 or ASTM A240/A240M.

a. [**Sheet and roll stock ready for shop or field sizing**] [**Factory cut and rolled to size**].
b. Material, finish, and thickness are indicated in field-applied jacket schedules.

Among the three moisture barriers in first subparagraph below, 1-mil (0.025-mm) barrier provides the least protection against galvanic corrosion, 3-mil (0.075-mm) barrier offers better protection, and polysurlyn barrier offers the best protection. For most indoor applications, 1-mil (0.025-mm) barrier is adequate.

c. Moisture Barrier for Indoor Applications: [**1-mil-thick, heat-bonded polyethylene and kraft paper**] [**3-mil-thick, heat-bonded polyethylene and kraft paper**] [**2.5-mil-thick polysurlyn**].
d. Moisture Barrier for Outdoor Applications: [**3-mil-thick, heat-bonded polyethylene and kraft paper**] [**2.5-mil-thick polysurlyn**].

E. Self-Adhesive Outdoor Jacket: 60-mil-thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with [**white**] [**stucco-embossed**] aluminum-foil facing.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. <**Insert manufacturer's name**>.

2.11 TAPES

Product performance is based on products manufactured by Venture Tape; there are slight variations among manufacturers.

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C1136.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Avery Dennison Corporation, Specialty Tapes Division.
b. Compac Corporation.
c. Ideal Tape Co., Inc., an American Biltrite Company.
d. Knauf Insulation.

2. Width: 3 inches.
3. Thickness: 11.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C1136.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Avery Dennison Corporation, Specialty Tapes Division.
b. Compac Corporation.
c. Ideal Tape Co., Inc., an American Biltrite Company.
d. Knauf Insulation.

2. Width: 3 inches.
3. Thickness: 6.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Compac Corporation.
b. Ideal Tape Co., Inc., an American Biltrite Company.

2. Width: 2 inches.
3. Thickness: 6 mils.
4. Adhesion: 64 ounces force/inch in width.
5. Elongation: 500 percent.
6. Tensile Strength: 18 lbf/inch in width.

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Avery Dennison Corporation, Specialty Tapes Division.
b. Compac Corporation.
c. Ideal Tape Co., Inc., an American Biltrite Company.
d. Knauf Insulation.

2. Width: 2 inches.
3. Thickness: 3.7 mils.
4. Adhesion: 100 ounces force/inch in width.
5. Elongation: 5 percent.
6. Tensile Strength: 34 lbf/inch in width.

2.12 SECUREMENTS

A. Bands:

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. ITW Insulation Systems; Illinois Tool Works, Inc.

Wing seals are primarily used for fastening bands together. Closed seals are occasionally used for large, 84-inch- (2130-mm-) diameter applications and where fastening bands are used with springs. Wing seals are reusable; closed seals are not.

2. Stainless Steel: ASTM A167 or ASTM A240/A240M, [**Type 304**] [**or**] [**Type 316**]; 0.015 inch thick, [**1/2 inch**] [**3/4 inch**] wide with [**wing seal**] [**or**] [**closed seal**].
3. Aluminum: ASTM B209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, [**1/2 inch**] [**3/4 inch**] wide with [**wing seal**] [**or**] [**closed seal**].

Springs are used for large, 84-inch- (2130-mm-) diameter applications and on applications with rapid changes in expansion and contraction.

4. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.

B. Insulation Pins and Hangers:

1. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, [**0.106-inch-**] [**0.135-inch-**] diameter shank, length to suit depth of insulation indicated.

   a. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

      1) AGM Industries, Inc.
      2) Gemco.
      3) Hardcast; a Carlisle Company.
      4) Midwest Fasteners, Inc.

2. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, [**0.106-inch-**] [**0.135-inch-**] diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.

   a. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

      1) AGM Industries, Inc.
      2) CL WARD & Family Inc.
      3) Gemco.
      4) Hardcast; a Carlisle Company.
      5) Midwest Fasteners, Inc.

3. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

   a. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

      1) AGM Industries, Inc.
      2) Gemco.

   b. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
   c. Spindle: [**Copper- or zinc-coated, low-carbon steel**] [**Aluminum**] [**Stainless steel**], fully annealed, 0.106-inch-diameter shank, length to suit depth of insulation indicated.

d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

4. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

   a. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

      1) Gemco.

   b. Baseplate: Perforated, nylon sheet, 0.030 inch thick by 1-1/2 inches in diameter.
   c. Spindle: Nylon, 0.106-inch-diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches.
   d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

5. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

   a. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

      1) AGM Industries, Inc.
      2) Gemco.
      3) Hardcast; a Carlisle Company.

   b. Baseplate: Galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
   c. Spindle: [**Copper- or zinc-coated, low-carbon steel**] [**Aluminum**] [**Stainless steel**], fully annealed, 0.106-inch-diameter shank, length to suit depth of insulation indicated.
   d. Adhesive-backed base with a peel-off protective cover.

6. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick, [**galvanized-steel**] [**aluminum**] [**stainless-steel**] sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

   a. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

1) AGM Industries, Inc.
2) Gemco.
3) Hardcast; a Carlisle Company.
4) Midwest Fasteners, Inc.

b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

7. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

a. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

1) Gemco.

C. Staples: Outward-clinching insulation staples, nominal 3/4-inch-wide, stainless steel or Monel.

In paragraph below, stainless steel is the most common wire used and is best suited for all applications.

D. Wire: [**0.080-inch nickel-copper alloy**] [**0.062-inch soft-annealed, stainless steel**] [**0.062-inch soft-annealed, galvanized steel**].

1. Manufacturers: Subject to compliance with requirements, [**provide products by the following**] [**provide products by one of the following**] [**available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following**]:

a. <**Insert manufacturer's name**>.

2.13 CORNER ANGLES

A. PVC Corner Angles: [**30 mils**] <**Insert dimension**> thick, minimum 1 by 1 inch, PVC according to ASTM D1784, Class 16354-C. White or color-coded to match adjacent surface.

B. Aluminum Corner Angles: [**0.040 inch**] <**Insert dimension**> thick, minimum 1 by 1 inch, aluminum according to ASTM B209, Alloy 3003, 3005, 3105, or 5005; Temper H-14.

C. Stainless-Steel Corner Angles: [**0.024 inch**] <**Insert dimension**> thick, minimum 1 by 1 inch, stainless steel according to ASTM A167 or ASTM A240/A240M, [**Type 304**] [**or**] [**Type 316**].

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.

B. Install insulation materials, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Keep insulation materials dry during application and finishing.

G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

H. Install insulation with least number of joints practical.

I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

K. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.

2. Cover circumferential joints with 3-inch-wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at [**2 inches**] [**4 inches**] o.c.

    a. For below ambient services, apply vapor-barrier mastic over staples.

4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.

L. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

3.4 PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
4. Seal jacket to wall flashing with flashing sealant.

C. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

D. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches.

1. Comply with requirements in Section 078413 "Penetration Firestopping."

E. Insulation Installation at Floor Penetrations:

1. Duct: For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches.
2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.5 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.6 INSTALLATION OF MINERAL-FIBER INSULATION

A. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

In first subparagraph below, many manufacturers do not recommend 100 percent coverage of adhesive because of the effect on the overall insulation system's fire-performance characteristics. Verify application coverage recommendations with insulation manufacturer.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for [**100**] [**50**] <**Insert number**> percent coverage of duct and plenum surfaces.

Revise first subparagraph below to allow adhesive to be omitted from top surface of horizontal rectangular ducts.

2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

   a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
   b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
   c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
   d. Do not overcompress insulation during installation.

e. Impale insulation over pins and attach speed washers.
f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

   a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
   b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

5. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.
6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

B. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

In first subparagraph below, many manufacturers do not recommend 100 percent coverage of adhesive because of the effect on the overall insulation system's fire-performance characteristics. Verify application coverage recommendations with insulation manufacturer.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for [**100**] [**50**] <**Insert number**> percent coverage of duct and plenum surfaces.

Revise first subparagraph below to allow adhesive to be omitted from top surface of horizontal rectangular ducts.

2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

   a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.

b. On duct sides with dimensions larger than 18 inches, space pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
d. Do not overcompress insulation during installation.
e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.7 FIELD-APPLIED JACKET INSTALLATION

A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.

1. Draw jacket smooth and tight to surface with 2-inch overlap at seams and joints.
2. Embed glass cloth between two 0.062-inch-thick coats of lagging adhesive.
3. Completely encapsulate insulation with coating, leaving no exposed insulation.

B. Where FSK jackets are indicated, install as follows:

1. Draw jacket material smooth and tight.
2. Install lap or joint strips with same material as jacket.
3. Secure jacket to insulation with manufacturer's recommended adhesive.
4. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch-wide joint strips at end joints.
5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

C. Where PVC jackets are indicated, install with 1-inch overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturer's recommended adhesive.

1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.

D. Where metal jackets are indicated, install with 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 12 inches o.c. and at end joints.

3.8 FIRE-RATED INSULATION SYSTEM INSTALLATION

A. Where fire-rated insulation system is indicated, secure system to ducts and duct hangers and supports to maintain a continuous fire rating.

B. Insulate duct access panels and doors to achieve same fire rating as duct.

C. Install firestopping at penetrations through fire-rated assemblies. Fire-stop systems are specified in Section 078413 "Penetration Firestopping."

3.9 FINISHES

Coordinate first paragraph below with Section 099113 "Exterior Painting" and Section 099123 "Interior Painting." If PVC jackets are specified, consult jacket manufacturers to determine suitable paint products and revise painting Sections to suit Project.

A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

Retain paint system in subparagraphs below for a flat, latex-emulsion size over insulation covering an exterior that is subject to normal use and moderate environments.

1. Flat Acrylic Finish: [**Two**] <**Insert number**> finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

a. Finish Coat Material: Interior, flat, latex-emulsion size.

B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.

C. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

D. Do not field paint aluminum or stainless-steel jackets.

3.10 FIELD QUALITY CONTROL

Inspections in this article are destructive. Retain if workmanship quality is an important requirement. Architect should be prepared to reject all work if defective work is discovered in sample inspection.

Retain one of first two paragraphs below to identify who shall perform tests and inspections. If retaining second option in first paragraph, or if retaining second paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to perform tests and inspections.

B. Perform tests and inspections.

Retain first paragraph below to describe tests and inspections to be performed.

C. Tests and Inspections:

1. Inspect ductwork, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to [**one**] <**Insert number**> location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

Materials and thicknesses in schedules below are for single-layer applications. If multilayer applications are needed, insert additional requirements.

3.11 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation:

1. Indoor, concealed supply and outdoor air.
2. Indoor, exposed supply and outdoor air.
3. Indoor, concealed return located in unconditioned space.
4. Indoor, exposed return located in unconditioned space.
5. Indoor, concealed, Type I, commercial, kitchen hood exhaust.
6. Indoor, exposed, Type I, commercial, kitchen hood exhaust.
7. Indoor, concealed oven and warewash exhaust.
8. Indoor, exposed oven and warewash exhaust.
9. Indoor, concealed exhaust between isolation damper and penetration of building exterior.
10. Indoor, exposed exhaust between isolation damper and penetration of building exterior.
11. Outdoor, concealed supply and return.
12. Outdoor, exposed supply and return.

B. Items Not Insulated:

1. Fibrous-glass ducts.
2. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
3. Factory-insulated flexible ducts.
4. Factory-insulated plenums and casings.
5. Flexible connectors.
6. Vibration-control devices.
7. Factory-insulated access panels and doors.

Duct and plenum insulation schedules in first two articles below specify commonly used insulation materials and thicknesses for each service type. LEED Prerequisite EA 2 requires that duct insulation R-value comply with ASHRAE/IESNA 90.1 tables titled "Minimum Duct Insulation R-Value, Cooling and Heating Only Supply Ducts and Return Ducts" and "Minimum Duct Insulation R-Value, Combined Heating and Cooling Supply Ducts and Return Ducts." Not all materials and thicknesses may be suitable for a specific project. Revise to suit Project after considering all parameters that impact selection. Do not duplicate requirements inserted in "Insulation Materials" Article. See Evaluations for more information and guidance.

Flexible elastomeric and polyolefin thicknesses are limited to 1 inch (25 mm) to meet a flame-spread index of 25 and a smoke-developed index of 50. Condensation control and energy efficiency are limited by thickness.

Consider the exposure of installed insulation to damage. Concealed applications have less risk than exposed.

3.12 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

See the Insulation Evaluation tables in the Evaluations for rankings of different insulation types for different service ranges.

Retain "one of" option in paragraphs below to allow Contractor to select piping materials from those retained.

A. Concealed, round and flat-oval, supply-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

B. Concealed, round and flat-oval, return-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

C. Concealed, round and flat-oval, outdoor-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

D. Concealed, round and flat-oval, exhaust-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

E. Concealed, rectangular, supply-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

F. Concealed, rectangular, return-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

G. Concealed, rectangular, outdoor-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

H. Concealed, rectangular, exhaust-air duct insulation between isolation damper and penetration of building exterior shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

I. Concealed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated [**blanket**] [**or**] [**board**]; thickness as required to achieve 2-hour fire rating.

J. Concealed, supply-air plenum insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

K. Concealed, return-air plenum insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

L. Concealed, outdoor-air plenum insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

M. Concealed, exhaust-air plenum insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

N. Exposed, round and flat-oval, supply-air duct insulation shall be[**one of**] the following:

Retain one or more of five subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Mineral-Fiber Pipe and Tank: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
5. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

O. Exposed, round and flat-oval, return-air duct insulation shall be[**one of**] the following:

Retain one or more of five subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Mineral-Fiber Pipe and Tank: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
5. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

P. Exposed, round and flat-oval, outdoor-air duct insulation shall be[**one of**] the following:

Retain one or more of five subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Mineral-Fiber Pipe and Tank: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.

5. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

Q. Exposed, round and flat-oval, exhaust-air duct insulation shall be[**one of**] the following:

Retain one or more of five subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Mineral-Fiber Pipe and Tank: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
5. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

R. Exposed, rectangular, supply-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

S. Exposed, rectangular, return-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

T. Exposed, rectangular, outdoor-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

U. Exposed, rectangular, exhaust-air duct insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

V. Exposed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated [**blanket**] [**or**] [**board**]; thickness as required to achieve 2-hour fire rating.

W. Exposed, supply-air plenum insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

X. Exposed, return-air plenum insulation shall be[**one of**] the following:

Retain one or more of four subparagraphs below.

1. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
2. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
4. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

Y. Exposed, outdoor-air plenum insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

Z. Exposed, exhaust-air plenum insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

3.13 ABOVEGROUND, OUTDOOR DUCT AND PLENUM INSULATION SCHEDULE

See the Insulation Evaluation tables in the Evaluations for rankings of different insulation types for different service ranges.

Retain "one of" option in paragraphs below to allow Contractor to select piping materials from those retained.

To comply with ASHRAE/IESNA 90.1, insulation should have an R-value of 8 or higher.

A. Insulation materials and thicknesses are identified below. If more than one material is listed for a duct system, selection from materials listed is Contractor's option.

B. Concealed, round and flat-oval, supply-air duct insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

C. Concealed, round and flat-oval, return-air duct insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

D. Concealed, round and flat-oval, outdoor-air duct insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

E. Concealed, rectangular, supply-air duct insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

F. Concealed, rectangular, return-air duct insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

G. Concealed, supply-air plenum insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

H. Concealed, return-air plenum insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

I. Exposed, round and flat-oval, supply-air duct insulation shall be[**one of**] the following:

Retain one or more of three subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.
3. Mineral-Fiber Pipe and Tank: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.

J. Exposed, round and flat-oval, return-air duct insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

K. Exposed, rectangular, supply-air duct insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

L. Exposed, rectangular, return-air duct insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

M. Exposed, supply-air plenum insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

N. Exposed, return-air plenum insulation shall be[**one of**] the following:

Retain one or both subparagraphs below.

1. Mineral-Fiber Blanket: [**2 inches**] [**3 inches**] <**Insert dimension**> and [**0.75-lb/cu. ft.**] [**1.5-lb/cu. ft.**] [**3-lb/cu. ft.**] nominal density.
2. Mineral-Fiber Board: [**2 inches**] [**3 inches**] <**Insert dimension**> thick and [**2-lb/cu. ft.**] [**3-lb/cu. ft.**] [**6-lb/cu. ft.**] nominal density.

3.14 INDOOR, FIELD-APPLIED JACKET SCHEDULE

Possible variations of jackets by location are endless. This article specifies locations in two broad categories: concealed and exposed. Revise if additional delineation is necessary.

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Ducts and Plenums, Concealed:

Retain one of six subparagraphs below.

1. None.
2. [**PVC**] [**PVC, Color-Coded by System**]: [**20 mils**] [**30 mils**] thick.
3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] [**0.040 inch**] thick.
4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] thick.
5. Stainless Steel, [**Type 304**] [**or**] [**Type 316**], [**Smooth 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch**] [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] thick.
6. <**Insert jacket type**>.

D. Ducts and Plenums, Exposed:

Retain one of six subparagraphs below.

1. None.
2. [**PVC**] [**PVC, Color-Coded by System**]: [**20 mils**] [**30 mils**] thick.
3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] [**0.040 inch**] thick.
4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] thick.
5. Stainless Steel, [**Type 304**] [**or**] [**Type 316**], [**Smooth 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch**] [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] thick.
6. <**Insert jacket type**>.

3.15 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

Possible variations of jackets by location are endless. This article specifies locations in two broad categories: concealed and exposed. Revise if additional delineation is necessary.

30-mil (0.8-mm) or heavier PVC is recommended for outdoor applications. 40-mil (1.0-mm) PVC does not meet a flame-spread index of 25 and a smoke-developed index of 50; however, a flame-spread or smoke-developed index is not a requirement for outdoor applications.

0.024-inch (0.61-mm) or heavier aluminum is recommended for outdoor applications.

Painted aluminum increases surface emissivity and provides added chemical resistance. See Evaluations for discussion of emissivity.

0.016-inch (0.41-mm) or heavier stainless steel is recommended for outdoor applications.

Z-shaped locking seam is recommended for metal jackets located in unprotected applications that are exposed to severe weather.

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Ducts and Plenums, Concealed:

Retain one of six subparagraphs below.

1. None.
2. [**PVC**] [**PVC, Color-Coded by System**]: [**20 mils**] [**30 mils**] thick.
3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] [**0.040 inch**] thick.
4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] thick.
5. Stainless Steel, [**Type 304**] [**or**] [**Type 316**], [**Smooth 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch**] [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] thick.

6. <**Insert jacket type**>.

D. Ducts and Plenums, Exposed, up to 48 Inches in Diameter or with Flat Surfaces up to 72 Inches:

Retain one of four subparagraphs below.

1. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] [**0.040 inch**] thick.
2. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] thick.
3. Stainless Steel, [**Type 304**] [**or**] [**Type 316**], [**Smooth 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch**] [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] thick.
4. <**Insert jacket type**>.

E. Ducts and Plenums, Exposed, Larger Than 48 Inches in Diameter or with Flat Surfaces Larger Than 72 Inches:

Retain one of three subparagraphs below.

1. [**Painted**]Aluminum, [**Smooth**] [**Stucco Embossed**] with [**1-1/4-Inch-Deep Corrugations**] [**2-1/2-Inch-Deep Corrugations**] [**4-by-1-Inch Box Ribs**]: [**0.032 inch**] [**0.040 inch**] thick.
2. Stainless Steel, [**Type 304**] [**or**] [**Type 316**], [**Smooth**] [**Stucco Embossed**], with [**1-1/4-Inch-Deep Corrugations**] [**2-1/2-Inch-Deep Corrugations**] [**4-by-1-Inch Box Ribs**]: [**0.020 inch**] [**0.024 inch**] thick.
3. <**Insert jacket type**>.

END OF SECTION 230713

SECTION 230719 - HVAC PIPING INSULATION

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on Masterworks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on Masterworks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes insulation for HVAC piping systems.

B. Related Sections:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 230713 "Duct Insulation" for duct insulation.
2. Section 230716 "HVAC Equipment Insulation" for equipment insulation.
3. Section 232113.13 "Underground Hydronic Piping" loose-fill pipe insulation in underground piping outside the building.
4. Section 336313 "Underground Steam and Condensate Distribution Piping" for loose-fill pipe insulation in underground piping outside the building.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied if any).

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for adhesives, mastics, and sealants submittals.>

C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
2. Detail attachment and covering of heat tracing inside insulation.
3. Detail insulation application at pipe expansion joints for each type of insulation.
4. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
5. Detail removable insulation at piping specialties.
6. Detail application of field-applied jackets.
7. Detail application at linkages of control devices.

Retain "Samples" Paragraph below to verify products with Samples.

D. Samples: For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use.

1. Preformed Pipe Insulation Materials: 12 inches long by NPS 2.
2. Sheet Form Insulation Materials: 12 inches square.
3. Jacket Materials for Pipe: 12 inches long by NPS 2.
4. Sheet Jacket Materials: 12 inches square.
5. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.4 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

A. Qualification Data: For qualified Installer.

Retain "Material Test Reports" Paragraph below if surface-burning characteristics specified in "Quality Assurance" Article are specified to be verified by an independent testing agency.

B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

1.5 QUALITY ASSURANCE

Retain "Installer Qualifications" Paragraph below if available at Project location. Apprenticeship programs are usually associated with union shops. Other craft training programs are available.

A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.

When fire-performance characteristics are important requirements, verify surface-burning characteristics of insulation materials by an independent testing agency and require test report submittals.

B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products in accordance with ASTM E84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

If retaining "Mockups" Paragraph below, indicate location, size, and other details of mockups on Drawings or by inserts. Revise if only one mockup is required. Edit mockups to retain those specific to Project. Provide additional mockup requirements if applicable.

C. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by Architect. Use materials indicated for the completed Work.

1. Piping Mockups:

a. One 10-foot section of NPS 2 straight pipe.
b. One each of a 90 degree threaded, welded, and flanged elbow.

c. One each of a threaded, welded, and flanged tee fitting.
d. One NPS 2 or smaller valve and one NPS 2-1/2 or larger valve.
e. Four support hangers, including hanger shield and insert.
f. One threaded strainer and one flanged strainer with removable portion of insulation.
g. One threaded reducer and one welded reducer.
h. One pressure temperature tap.
i. One mechanical coupling.
j. One union.
k. <**Insert mockup**>

2. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
3. Notify Architect [**seven**] <**Insert number**> days in advance of dates and times when mockups will be constructed.
4. Obtain Architect's approval of mockups before starting insulation application.

Retain first subparagraph below if mockups are not only for establishing appearance factors.

5. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
6. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
7. Demolish and remove mockups when directed.

1.6 DELIVERY, STORAGE, AND HANDLING

Retain this article to require shipping container markings. Container marking is an option in ASTM International standards; default condition does not include the marking in this article unless specified in the Contract.

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.7 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

Retain subparagraph below for projects that have heat tracing on piping.

C. Coordinate installation and testing of heat tracing.

1.8 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 INSULATION MATERIALS

If retaining more than one type of insulation in this article, indicate where each type applies in insulation system schedules.

A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," "Outdoor, Aboveground Piping Insulation Schedule," and "Outdoor, Underground Piping Insulation Schedule" articles for where insulating materials shall be applied.

See "Product Characteristics" Article in the Evaluations for comparisons and temperature ranges for insulation material properties.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come into contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested in accordance with ASTM C871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable in accordance with ASTM C795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Calcium Silicate: Preformed Pipe Sections: Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C533, Type I.

   1. Prefabricated Fitting Covers: Comply with ASTM C450 and ASTM C585 for dimensions used in preforming insulation to cover valves, elbows, tees, and flanges.

   2. <Double click here to find, evaluate, and insert list of manufacturers and products.>

G. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Comply with ASTM C552.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Preformed Pipe Insulation: Type II, Class 1, without jacket.
3. Preformed Pipe Insulation: Type II, Class 2, with factory-applied [**ASJ**] [**ASJ-SSL**] jacket.
4. Factory fabricate shapes in accordance with ASTM C450 and ASTM C585.
5. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

"Flexible Elastomeric" Paragraph below is unsuitable for temperatures of lower than minus 70 deg F (minus 57 deg C) and higher than 220 deg F (104 deg C).

In "Flexible Elastomeric" Paragraph below, sheet material option is included for larger piping. Tubular materials are generally only available in sections of up to 8 to 10 inches (200 to 250 mm), depending on manufacturer.

H. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C534/C534M, Type I for tubular materials, Type II for sheet materials.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

I. Mineral-Fiber, Preformed Pipe: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C547.

An ASJ requires field-applied adhesive and staples. An ASJ-SSL does not require field-applied adhesive and staples, resulting in reduced installation labor.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Preformed Pipe Insulation: Type I, Grade A[**, without factory-applied jacket**][**with factory-applied ASJ**][**with factory-applied ASJ-SSL**].
3. 850 deg F.
4. Factory fabricate shapes in accordance with ASTM C450 and ASTM C585.
5. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

Pipe and tank insulation is used for large-diameter piping and vessels. ASJ is commonly used.

J. Mineral-Fiber, Pipe and Tank: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C1393.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Semirigid board material with factory-applied [**ASJ**] [**FSK**] jacket.
3. Nominal density is 2.5 lb/cu. ft. or more.
4. Thermal conductivity (k-value) at 100 deg F is 0.29 Btu x in./h x sq. ft. x deg F or less.
5. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

Phenolic insulation is available in Grades 1 and 2. Grade 1 has a lower thermal conductivity than Grade 2. Grade 2 is not commercially available.

K. Phenolic: Preformed pipe insulation of rigid, expanded, closed-cell structure. Comply with ASTM C1126.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Preformed Pipe Insulation: Type III[**, without factory-applied jacket**] [**, with factory-applied ASJ**].
3. Factory fabricate shapes in accordance with ASTM C450 and ASTM C585.
4. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

L. Polyisocyanurate: Preformed, rigid cellular polyisocyanurate material intended for use as thermal insulation. Comply with ASTM C591.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Preformed insulation[**, without factory-applied jacket**] [**, with factory-applied ASJ**] [**, with factory-applied ASJ-SSL**] [**, with field-applied PVDC jacket**] [**, with field-applied PVDC-SSL**].
3. Type IV, except thermal conductivity (k-value) shall not exceed 0.19 Btu x in./h x sq. ft. x deg F at 75 deg F after 180 days of aging.
4. Flame-spread index shall be 25 or less, and smoke-developed index shall be 50 or less for thicknesses of up to 1 inch as tested in accordance with ASTM E84.
5. Fabricate shapes in accordance with ASTM C450 and ASTM C585.
6. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

In "Polyolefin" Paragraph below, sheet material option is included for larger piping. Tubular materials are generally only available in sections of up to 4 inches (100 mm); consult manufacturer.

M. Polyolefin: Unicellular, polyethylene thermal plastic insulation. Comply with ASTM C534/C534M or ASTM C1427, Type I, Grade 1, for tubular materials and with Type II, Grade 1, for sheet materials.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Polystyrene is for outdoor use only; its flame-spread/smoke-developed indexes are unsuitable for most indoor applications.

N. Polystyrene: Rigid, extruded cellular polystyrene intended for use as thermal insulation. Comply with ASTM C578, Type IV or Type XIII, except thermal conductivity (k-value) shall not exceed 0.26 Btu x in./h x sq. ft. x deg F after 180 days of aging. Fabricate shapes in accordance with ASTM C450 and ASTM C585.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.2 INSULATING CEMENTS

Mineral-fiber insulating cement is suitable for temperatures from 100 to 1600 deg F (38 to 871 deg C). Vermiculite insulating cement is suitable for temperatures from 100 to 1800 deg F (38 to 982 deg C).

A. Mineral-Fiber Insulating Cement: Comply with ASTM C195.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C196.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Mineral-fiber, hydraulic-setting cement is suitable for temperatures from 100 to 1200 deg F (38 to 649 deg C) and for a smooth surface.

C. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C449.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.3 ADHESIVES

MIL-A-3316C was the only standard available when this Section was updated. MIL-A-3316C was last updated in 1990.

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 50 to 800 deg F.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. <Double click to insert sustainable design text for calcium silicate adhesive VOC content.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

C. Cellular-Glass Adhesive: Two-component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of minus 100 to plus 200 deg F.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. <Double click to insert sustainable design text for cellular glass adhesive VOC Content.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

D. Phenolic and Polyisocyanurate Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. <Double click to insert sustainable design text for phenolic and polyisocyanurate adhesive VOC content.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

E. Flexible Elastomeric and Polyolefin Adhesive: Solvent-based adhesive.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Not all manufacturer comply with sustainability requirements. If sustainability is a Project goal, consult manufacturers.

2. <Double click to insert sustainable design text for adhesive for flexible elastomeric and polyolefin VOC content.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

4. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less as tested in accordance with ASTM E84.
5. Wet Flash Point: Below 0 deg F.
6. Service Temperature Range: 40 to 200 deg F.
7. Color: [**Black**] <**Insert color**>.

F. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. <Double click to insert sustainable design text for mineral fiber adhesive VOC content>
3. <Double click to insert sustainable design text for low emitting adhesives.>

G. Polystyrene Adhesive: Solvent- or water-based, synthetic resin adhesive with a service temperature range of minus 20 to plus 140 deg F.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. <Double click to insert sustainable design text for polystyrene adhesive VOC content.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

H. ASJ Adhesive and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A, for bonding insulation jacket lap seams and joints.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. <Double click to insert sustainable design text for adhesive for ASJ, FSK, and PVDC jackets VOC content.>
3. <Double click to insert sustainable design text for low emitting adhesives.>

I. PVC Jacket Adhesive: Compatible with PVC jacket.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Not all manufacturers comply with sustainability requirements. If sustainability is a Project goal, consult manufacturers.

2. <Double click to insert sustainable design text for adhesive for PVC jacket>
3. <Double click to insert sustainable design text for low emitting adhesives.>

2.4 MASTICS AND COATINGS

Mastic and coating terminology is used interchangeably in this article. Manufacturers refer to vapor-barrier formulations and vapor-retarder formulations as "mastics" or "coatings." Low-permeance mastics and coatings are termed "vapor retarders." Products with a perm rating of greater than 1.0 are called "breathable." Consider ambient conditions and operating temperatures when selecting mastics and coatings. Consider using water-based mastics and coatings for environmental reasons.

LEED 2009 IEQ Credit 4.1 does not address requirements for mastics and coatings. LEED 2009 IEQ Credit 4.2 does address requirements for mastics and coatings. LEED v4 EQ Credit, "Low-Emitting Materials," does address requirements for mastics and coatings.

A. Materials shall be compatible with insulation materials, jackets, and substrates.

1. <Double click to insert sustainable design text for insulation mastics VOC content.>
2. <Double click to insert sustainable design text for low-emitting mastics VOC content.>

Verify that products listed comply with water-vapor permeance requirements. Require proof of performance and certified test reports from vapor-barrier mastic manufacturer, to support product literature claims.

Retain "Vapor-Retarder Mastic, Water Based," "Vapor-Retarder Mastic, Solvent Based, Indoor Use" "Vapor-Retarder Mastic, Solvent Based, Outdoor Use," or "Breather Mastic" Paragraph below. Consider insulation type and operating conditions when selecting mastics and coatings.

B. Vapor-Retarder Mastic, Water Based: Suitable for indoor use on below-ambient services.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.

In "Service Temperature Range" Subparagraph below, more manufacturers can comply if first option is retained; consult manufacturers.

3. Service Temperature Range: [**0 to plus 180 deg F**] [**Minus 20 to plus 180 deg F**].

Retain MIL-PRF-19565C in first subparagraph below for vapor-retarder mastics and coatings if applicable to Project.

4. Comply with MIL-PRF-19565C, Type II, for permeance requirements[**, with supplier listing on DOD QPD - Qualified Products Database**].
5. Color: [**White**] <**Insert color**>.

Retain "Vapor-Retarder Mastic, Solvent Based, Indoor Use" Paragraph below if low-VOC mastics and coatings are not required, or if a lower permeance is required.

C. Vapor-Retarder Mastic, Solvent Based, Indoor Use: Suitable for indoor use on below-ambient services.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
3. Service Temperature Range: 0 to 180 deg F.
4. Color: [**White**] <**Insert color**>.

D. Vapor-Retarder Mastic, Solvent Based, Outdoor Use: Suitable for outdoor use on below-ambient services.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
3. Service Temperature Range: Minus 50 to plus 220 deg F.
4. Color: [**White**] <**Insert color**>.

E. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Water-Vapor Permeance: ASTM E96/E96M, greater than 1.0 perm at manufacturer's recommended dry film thickness.

In "Service Temperature Range" Subparagraph below, more manufacturers can comply if first option is retained; consult manufacturers.

3. Service Temperature Range: [**0 to plus 180 deg F**] [**Minus 20 to plus 180 deg F**].
4. Color: [**White**] <**Insert color**>.

2.5 LAGGING ADHESIVES

A. Adhesives shall comply with MIL-A-3316C, Class I, Grade A, and shall be compatible with insulation materials, jackets, and substrates.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. <Double click to insert sustainable design text for lagging adhesives.>
3. <Double click to insert sustainable design text for low emitting adhesives.>
4. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.

In "Service Temperature Range" Subparagraph below, more manufacturers can comply if first option is retained; consult manufacturers.

5. Service Temperature Range: [**20 to plus 180 deg F**] [**0 to plus 180 deg F**].
6. Color: White.

2.6 SEALANTS

Sealants are categorized into "joint sealants" and "flashing sealants." Joint sealants are primarily used for vapor-sealing longitudinal seams and butt joints of insulation materials. Flashing sealants are primarily used for sealing jacket and mastic materials.

A. Materials shall be as recommended by the insulation manufacturer and shall be compatible with insulation materials, jackets, and substrates.

B. Joint Sealants:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Permanently flexible, elastomeric sealant.

In "Service Temperature Range" Subparagraph below, more manufacturers can comply if first option is retained; consult manufacturers.

   a. Service Temperature Range: [**Minus 150 to plus 250 deg F**] [**Minus 100 to plus 300 deg F**].
   b. Color: White or gray.

3. <Double click to insert sustainable design text for sealant.>
4. <Double click to insert sustainable design text for sealants.>

Materials in "FSK and Metal Jacket Flashing Sealants" Paragraph below are for sealing metal jacket seams and joints.

C. FSK and Metal Jacket Flashing Sealants:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F.
4. Color: Aluminum.
5. <Double click to insert sustainable design text for sealant.>
6. <Double click to insert sustainable design text for sealants.>

D. ASJ Flashing Sealants and PVDC and PVC Jacket Flashing Sealants:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F.
4. Color: White.
5. <Double click to insert sustainable design text for sealant.>
6. <Double click to insert sustainable design text for sealants.>

2.7 FACTORY-APPLIED JACKETS

Coordinate types of factory-applied jacket insulation materials selected and types of factory-applied jackets indicated in insulation system schedules.

For insulation materials with factory-applied jackets for use on applications of greater than 140 deg F (60 deg C), specify sufficient insulation thickness to maintain outer surface temperature of insulation below 140 deg F (60 deg C). 140 deg F (60 deg C) surface temperature is set by OSHA for personnel protection.

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C1136, Type II.

2.8 FIELD-APPLIED FABRIC-REINFORCING MESH

Both glass-fiber- and polyester-fabric-reinforcing meshes are acceptable.

Retain "Woven Glass-Fiber Fabric" and "Woven Polyester Fabric" paragraphs below to give Contractor option to use either glass-fiber or polyester fabric.

A. Woven Glass-Fiber Fabric: Approximately 2 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in. for covering pipe and pipe fittings.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in., in a Leno weave, for pipe.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.9 FIELD-APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd..

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.10 FIELD-APPLIED JACKETS

Insulation jackets in this article are for field application. ASTM C1136, Type I, is for use over insulation on pipes operating at below-ambient temperatures at least part of the time or where a vapor barrier is required. ASTM C1136, Type II, is for use over insulation on pipes operating above-ambient temperatures or where a vapor retarder is not required.

A. Field-applied jackets shall comply with ASTM C1136, Type I, unless otherwise indicated.

A properly sealed FSK jacket, common with most forms of factory-applied jackets for mineral-fiber insulation, complies with vapor-retarder requirements of ASTM C1136, Type I.

B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

Although other thicknesses for PVC jackets are available, a flame-spread index of 25 and a smoke-developed index of 50 apply only to thicknesses of 30 mils (0.8 mm) and less.

C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Adhesive: As recommended by jacket material manufacturer.

PVC jackets are available in several colors. Colored jackets may be used to replace field painting. UV rays fade colors in exterior applications. Some colors (black, gray, and white) do not fade as quickly as other colors (red, orange, and green). Colored jackets have different emissivity and are not recommended for outdoor use.

3. Color: [**White**] [**Color-code jackets based on system. Color as selected by Architect**].
4. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.

   a. Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

D. Metal Jacket:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Aluminum Jacket: Comply with ASTM B209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.

a. [**Sheet and roll stock ready for shop or field sizing**] [**Factory cut and rolled to size**].
b. Finish and thickness are indicated in field-applied jacket schedules.

Among the three moisture barriers in "Moisture Barrier for Indoor Applications" Subparagraph below, 1-mil (0.025-mm) barrier provides the least protection against galvanic corrosion, 3-mil (0.075-mm) barrier offers better protection, and polysurlyn barrier offers the best protection. For most indoor applications, 1-mil (0.025-mm) barrier is adequate. For outdoor applications, retain either 3-mil (0.075-mm) or polysurlyn barrier.

c. Moisture Barrier for Indoor Applications: [**1-mil-thick, heat-bonded polyethylene and kraft paper**] [**3-mil-thick, heat-bonded polyethylene and kraft paper**] [**2.5-mil-thick polysurlyn**].
d. Moisture Barrier for Outdoor Applications: [**3-mil-thick, heat-bonded polyethylene and kraft paper**] [**2.5-mil-thick polysurlyn**].
e. Factory-Fabricated Fitting Covers:

1) Same material, finish, and thickness as jacket.
2) Preformed two-piece or gore, 45- and 90-degree, short- and long-radius elbows.
3) Tee covers.
4) Flange and union covers.
5) End caps.
6) Beveled collars.
7) Valve covers.
8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

3. Stainless-Steel Jacket: ASTM A240/A240M.

a. [**Sheet and roll stock ready for shop or field sizing**] [**Factory cut and rolled to size**].
b. Material, finish, and thickness are indicated in field-applied jacket schedules.

Among the three moisture barriers in "Moisture Barrier for Indoor Applications" Subparagraph below, 1-mil (0.025-mm) barrier provides the least protection against galvanic corrosion, 3-mil (0.075-mm) barrier offers better protection, and polysurlyn barrier offers the best protection. For most indoor applications, 1-mil (0.025-mm) barrier is adequate.

c. Moisture Barrier for Indoor Applications: [**1-mil-thick, heat-bonded polyethylene and kraft paper**] [**3-mil-thick, heat-bonded polyethylene and kraft paper**] [**2.5-mil-thick polysurlyn**].
d. Moisture Barrier for Outdoor Applications: [**3-mil-thick, heat-bonded polyethylene and kraft paper**] [**2.5-mil-thick polysurlyn**].
e. Factory-Fabricated Fitting Covers:

1) Same material, finish, and thickness as jacket.
2) Preformed two-piece or gore, 45- and 90-degree, short- and long-radius elbows.
3) Tee covers.
4) Flange and union covers.
5) End caps.
6) Beveled collars.

7) Valve covers.
8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

E. Underground Direct-Buried Jacket: 125-mil-thick vapor barrier and waterproofing membrane, consisting of a rubberized bituminous resin reinforced with a woven-glass fiber or polyester scrim and laminated aluminum foil.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

F. Self-Adhesive Outdoor Jacket: 60-mil-thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a cross-laminated polyethylene film covered with [**white**] [**stucco-embossed**] aluminum-foil facing.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

PVDC and PVDC-SSL jackets in "PVDC Jacket for Indoor Applications," "PVDC Jacket for Outdoor Applications," and "PVDC-SSL Jacket" paragraphs below are proprietary products offered by ITW Insulation Systems, Illinois Tool Works, Inc., under the product names "Saranex 540 CX Vapor Retarder Film" and "Saranex 560 CX Vapor Retarder Film."

G. PVDC Jacket for Indoor Applications: 4-mil-thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perms when tested in accordance with ASTM E96/E96M and with a flame-spread index of 10 and a smoke-developed index of 20 when tested in accordance with ASTM E84.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

H. PVDC Jacket for Outdoor Applications: 6-mil-thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perms when tested in accordance with ASTM E96/E96M and with a flame-spread index of 25 and a smoke-developed index of 50 when tested in accordance with ASTM E84.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

I. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.11 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C1136.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Width: [**3 inches**] <**Insert value**>.
3. Thickness: [**11.5 mils**] <**Insert value**>.
4. Adhesion: [**90 ounces force/inch**] <**Insert value**> in width.

5. Elongation: [**2**] <**Insert number**> percent.
6. Tensile Strength: [**40 lbf/inch**] <**Insert value**> in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C1136.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Width: [**3 inches**] <**Insert value**>.
3. Thickness: [**6.5 mils**] <**Insert value**>.
4. Adhesion: [**90 ounces force/inch**] <**Insert value**> in width.
5. Elongation: [**2**] <**Insert number**> percent.
6. Tensile Strength: [**40 lbf/inch**] <**Insert value**> in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Width: [**2 inches**] <**Insert value**>.
3. Thickness: [**6 mils**] <**Insert value**>.
4. Adhesion: [**64 ounces force/inch**] <**Insert value**> in width.
5. Elongation: [**500**] <**Insert number**> percent.
6. Tensile Strength: 18 lbf/inch in width.

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Width: [**2 inches**] <**Insert value**>.
3. Thickness: [**3.7 mils**] <**Insert value**>.
4. Adhesion: [**100 ounces force/inch**] <**Insert value**> in width.
5. Elongation: [**5**] <**Insert number**> percent.
6. Tensile Strength: [**34 lbf/inch**] <**Insert value**> in width.

PVDC tape is a proprietary product offered by ITW Insulation Systems, Illinois Tool Works, Inc., under the product names "Saranex 520 CX Vapor Retarder Tape" and "Saranex 560 CX Vapor Retarder Tape."

E. PVDC Tape for Indoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Width: [**3 inches**] <**Insert value**>.
3. Film Thickness: [**2 mils**] <**Insert value**>.
4. Adhesive Thickness: [**1.5 mils**] <**Insert value**>.
5. Elongation at Break: [**120**] <**Insert number**> percent.
6. Tensile Strength: [**20 psi**] <**Insert value**> in width.

F. PVDC Tape for Outdoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Width: [**3 inches**] <**Insert value**>.
3. Film Thickness: [**6 mils**] <**Insert value**>.

4. Adhesive Thickness: [**1.5 mils**] <**Insert value**>.
5. Elongation at Break: [**145**] <**Insert number**> percent.
6. Tensile Strength: [**55 psi**] <**Insert value**> in width.

2.12 SECUREMENTS

A. Bands:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Wing seals are primarily used for fastening bands together. Closed seals are occasionally used for large, 84-inch- (2130-mm-) diameter applications and where fastening bands are used with springs. Wing seals are reusable; closed seals are not.

2. Stainless Steel: ASTM A240/A240M, [**Type 304**] [**or**] [**Type 316**]; 0.015 inch thick, [**1/2 inch**] [**3/4 inch**] wide with [**wing seal**] [**or**] [**closed seal**].
3. Aluminum: ASTM B209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, [**1/2 inch**] [**3/4 inch**] wide with [**wing seal**] [**or**] [**closed seal**].

Springs are used for large, 84-inch- (2130-mm-) diameter applications and on applications with rapid changes in expansion and contraction.

4. Springs: Twin spring set constructed of stainless steel, with ends flat and slotted to accept metal bands. Spring size is determined by manufacturer for application.

B. Staples: Outward-clinching insulation staples, nominal 3/4 inch wide, stainless steel or Monel.

In "Wire" Paragraph below, stainless steel is the most common wire used and is best suited for all applications.

C. Wire: [**0.080-inch nickel-copper alloy**] [**0.062-inch soft-annealed, stainless steel**] [**0.062-inch soft-annealed, galvanized steel**].

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

Retain one of first two paragraphs below. Corrosion of metal pipe under insulation, although not typically caused by insulation, is an issue that must be considered during design of any HVAC insulation system. The potential for corrosion depends on many factors. Requirements cited in second paragraph represent added measures of protection but are not meant to take the place of proper system design and specification.

A. Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

B. Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:

1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 mils thick and an epoxy finish 5 mils thick if operating in a temperature range between 140 and 300 deg F. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
2. Carbon Steel: Coat carbon steel operating at a service temperature of between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

C. Coordinate insulation installation with the tradesman installing heat tracing. Comply with requirements for heat tracing that apply to insulation.

D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping, including fittings, valves, and specialties.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and of thicknesses required for each item of pipe system, as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

G. Keep insulation materials dry during storage, application, and finishing. Replace insulation materials that get wet.

H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

I. Install insulation with least number of joints practical.

J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends attached to structure with vapor-barrier mastic.
3. Install insert materials and insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

L. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.
2. Cover circumferential joints with 3-inch-wide strips, of same material as insulation jacket. Secure strips with adhesive and outward-clinching staples along both edges of strip, spaced 4 inches o.c.
3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward-clinching staples along edge at [**2 inches**] [**4 inches**] o.c.

   a. For below-ambient services, apply vapor-barrier mastic over staples.

4. Cover joints and seams with tape, in accordance with insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

M. Cut insulation in a manner to avoid compressing insulation more than 25 percent of its nominal thickness.

N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least [**4 inches** beyond damaged areas. Adhere, staple, and seal patches in similar fashion to butt joints.

P. For above-ambient services, do not install insulation to the following:

1. Vibration-control devices.

2. Testing agency labels and stamps.
3. Nameplates and data plates.

3.4 PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
4. Seal jacket to wall flashing with flashing sealant.

D. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

E. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.

1. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping and fire-resistive joint sealers.

F. Insulation Installation at Floor Penetrations:

1. Pipe: Install insulation continuously through floor penetrations.
2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.5 GENERAL PIPE INSULATION INSTALLATION

A. Requirements in this article generally apply to all insulation materials, except where more specific requirements are specified in various pipe insulation material installation articles.

Where pipe expansion is anticipated, detail expansion compensation for insulation on Drawings and indicate intervals for its occurrence. See the Midwest Insulation Contractors Association's "National Commercial & Industrial Insulation Standards," Plate No. 41A.

B. Insulation Installation on Fittings, Valves, Strainers, Flanges, Mechanical Couplings, and Unions:

1. Install insulation over fittings, valves, strainers, flanges, mechanical couplings, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
2. Insulate pipe elbows using [**preformed fitting insulation**] [**or**] [**mitered fittings**] made from same material and density as that of adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
3. Insulate tee fittings with [**preformed fitting insulation**] [**or**] [**sectional pipe insulation**] of same material and thickness as that used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
4. Insulate valves using [**preformed fitting insulation**] [**or**] [**sectional pipe insulation**] of same material, density, and thickness as that used for adjacent pipe. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
5. Insulate strainers using [**preformed fitting insulation**] [**or**] [**sectional pipe insulation**] of same material, density, and thickness as that used for adjacent pipe. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers, so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.
6. Insulate flanges, mechanical couplings, and unions using a section of oversized preformed pipe insulation to fit. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Stencil or label the outside insulation jacket of each union with the word "union" matching size and color of pipe labels.
7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
8. For services not specified to receive a field-applied jacket, except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing, using PVC tape.

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

Coordinate paragraph below with Drawings.

D. Install removable insulation covers[**at locations indicated**]. Installation shall conform to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as that of adjoining pipe insulation.
2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union at least 2 times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless steel or aluminum bands. Select band material compatible with insulation and jacket.
3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.
4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.6 INSTALLATION OF CALCIUM SILICATE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure single-layer insulation with stainless steel bands at 12-inch intervals, and tighten bands without deforming insulation materials.
2. Install two-layer insulation with joints tightly butted and staggered at least 3 inches. Secure inner layer with wire spaced at 12-inch intervals. Secure outer layer with stainless steel bands at 12-inch intervals.
3. Apply a skim coat of mineral-fiber, hydraulic-setting cement to insulation surface. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth or tape. Overlap edges at least 1 inch. Apply finish coat of lagging adhesive over glass cloth or tape. Thin finish coat to achieve smooth, uniform finish.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as that of pipe insulation.

4. Finish flange insulation same as pipe insulation.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as that of straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When preformed insulation sections of insulation are not available, install mitered sections of calcium silicate insulation. Secure insulation materials with wire or bands.
3. Finish fittings insulation same as pipe insulation.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install mitered segments of calcium silicate insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
2. Install insulation to flanges as specified for flange insulation application.
3. Finish valve and specialty insulation same as pipe insulation.

3.7 INSTALLATION OF CELLULAR-GLASS INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands, and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient services, secure laps with outward-clinched staples at 6 inches o.c.
4. For insulation with factory-applied jackets on below-ambient services, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as that of pipe insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as that of straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When preformed sections of insulation are not available, install mitered sections of cellular-glass insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of cellular-glass insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.8 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as that of pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed valve covers manufactured of same material as that of pipe insulation when available.
2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties, and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.9 INSTALLATION OF MINERAL-FIBER INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands, and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient surfaces, secure laps with outward-clinched staples at 6 inches o.c.

4. For insulation with factory-applied jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as that of straight segments of pipe insulation when available.
2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of same material as that of straight segments of pipe insulation when available.
2. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
4. Install insulation to flanges as specified for flange insulation application.

3.10 INSTALLATION OF PHENOLIC INSULATION

A. General Installation Requirements:

1. Secure single-layer insulation with stainless steel bands at 12-inch intervals, and tighten bands without deforming insulation materials.
2. Install two-layer insulation with joints tightly butted and staggered at least 3 inches. Secure inner layer with 0.062-inch wire spaced at 12-inch intervals. Secure outer layer with stainless steel bands at 12-inch intervals.

B. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands, and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient services, secure laps with outward-clinched staples at 6 inches o.c.

4. For insulation with factory-applied jackets with vapor retarders on below-ambient services, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic and flashing sealant.

C. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as that of pipe insulation.

D. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed insulation sections of same material as that of straight segments of pipe insulation. Secure according to manufacturer's written instructions.

E. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed insulation sections of same material as that of straight segments of pipe insulation. Secure according to manufacturer's written instructions.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.11 INSTALLATION OF POLYISOCYANURATE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with tape or bands and tighten without deforming insulation materials. Orient longitudinal joints between half sections in 3- and 9-o'clock positions on the pipe.
2. For insulation with factory-applied jackets with vapor barriers, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive or tape, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic.
3. All insulation shall be tightly butted and free of voids and gaps at all joints. Vapor barrier must be continuous. Before installing jacket material, install vapor-barrier system.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, and same thickness as that of adjacent pipe insulation, not to exceed 1-1/2-inch thickness.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyisocyanurate block insulation of same thickness as that of pipe insulation.

C. Insulation Installation on Fittings and Elbows:

1. Install preformed sections of same material as that of straight segments of pipe insulation. Secure according to manufacturer's written instructions.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of polyisocyanurate insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.12 INSTALLATION OF POLYOLEFIN INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Seal split-tube longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyolefin sheet insulation of same thickness as that of pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of polyolefin pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install cut sections of polyolefin pipe and sheet insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties, and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.13 INSTALLATION OF POLYSTYRENE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation with tape or bands and tighten bands without deforming insulation materials. Orient longitudinal joints between half sections in 3- and 9-o'clock positions on the pipe.
2. For insulation with factory-applied jackets with vapor barriers, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive or tape, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic.
3. All insulation shall be tightly butted and free of voids and gaps at all joints. Vapor barrier must be continuous. Before installing jacket material, install vapor-barrier system.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, and make thickness same as that of adjacent pipe insulation, not to exceed 1-1/2-inch.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polystyrene block insulation of same thickness that of as pipe insulation.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed insulation sections of same material as that of straight segments of pipe insulation. Secure according to manufacturer's written instructions.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed section of polystyrene insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.14 FIELD-APPLIED JACKET INSTALLATION

A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.

1. Draw jacket smooth and tight to surface with 2-inch overlap at seams and joints.
2. Embed glass cloth between two 0.062-inch-thick coats of lagging adhesive.
3. Completely encapsulate insulation with coating, leaving no exposed insulation.

B. Where FSK jackets are indicated, install as follows:

1. Draw jacket material smooth and tight.
2. Install lap or joint strips with same material as jacket.
3. Secure jacket to insulation with manufacturer's recommended adhesive.
4. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch-wide joint strips at end joints.
5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

C. Where PVC jackets are indicated and for horizontal applications, install with 1-inch overlap at longitudinal seams and end joints. Seal with manufacturer's recommended adhesive.

1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.

D. Where metal jackets are indicated, install with 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless steel bands 12 inches o.c. and at end joints.

E. Where PVDC jackets are indicated, install as follows:

1. Apply three separate wraps of filament tape per insulation section to secure pipe insulation to pipe prior to installation of PVDC jacket.
2. Wrap factory-presized jackets around individual pipe insulation sections, with one end overlapping the previously installed sheet. Install presized jacket with an approximate overlap at butt joint of 2 inches over the previous section. Adhere lap seal using adhesive or SSL, and then apply 1-1/4 circumferences of appropriate PVDC tape around overlapped butt joint.
3. Continuous jacket can be spiral-wrapped around a length of pipe insulation. Apply adhesive or PVDC tape at overlapped spiral edge. When electing to use adhesives, refer to manufacturer's written instructions for application of adhesives along this spiral edge to maintain a permanent bond.
4. Jacket can be wrapped in cigarette fashion along length of roll for insulation systems with an outer circumference of 33-1/2 inches or less. The 33-1/2-inch-circumference limit allows for 2-inch-overlap seal. Using the length of roll allows for longer sections of jacket to be installed at one time. Use adhesive on the lap seal. Visually inspect lap seal for "fishmouthing," and use PVDC tape along lap seal to secure joint.
5. Repair holes or tears in PVDC jacket by placing PVDC tape over the hole or tear and wrapping a minimum of 1-1/4 circumferences to avoid damage to tape edges.

3.15 FINISHES

Coordinate "Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material" Paragraph below with Section 099113 "Exterior Painting" and Section 099123 "Interior Painting." If specifying PVC jackets, consult jacket manufacturers to determine suitable paint products and revise painting Sections to suit Project.

A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

Retain paint system in "Flat Acrylic Finish" Subparagraph below for a flat, latex-emulsion size over insulation covering an exterior that is subject to normal use and moderate environments.

1. Flat Acrylic Finish: [**Two**] <**Insert number**> finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

a. Finish Coat Material: Interior, flat, latex-emulsion size.

B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.

C. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

D. Do not field paint aluminum or stainless steel jackets.

3.16 FIELD QUALITY CONTROL

Inspections in this article are destructive. Retain if workmanship quality is an important requirement. Architect should be prepared to reject all work if defective work is discovered in sample inspection.

Retain one of first four paragraphs below. Retain first paragraph below if Owner will hire an independent testing agency.

A. Owner will engage a qualified testing agency to perform tests and inspections.

Retain first paragraph below to require Contractor to hire an independent testing agency.

B. Engage a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform tests and inspections" Paragraph below to require Contractor to perform tests and inspection, and retain option to require Contractor to arrange for the assistance of a factory-authorized service agent.

D. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].

Retain test requirements in "Tests and Inspections" Paragraph below with any combination of paragraphs above.

E. Tests and Inspections: Inspect pipe, fittings, strainers, and valves, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to [**three**] <**Insert number**> locations of straight pipe, [**three**] <**Insert number**> locations of threaded fittings, [**three**] <**Insert number**> locations of welded fittings, [**two**] <**Insert number**> locations of threaded strainers, [**two**] <**Insert number**> locations of welded strainers, [**three**] <**Insert number**> locations of threaded valves, and [**three**] <**Insert number**> locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General" Article.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

F. All insulation applications will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports.

Materials and thicknesses in schedules below are for single-layer applications. If multilayer applications are needed, insert additional requirements.

3.17 PIPING INSULATION SCHEDULE, GENERAL

A. Insulation conductivity and thickness per pipe size shall comply with schedules in this Section or with requirements of authorities having jurisdiction, whichever is more stringent.

B. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.

C. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:

Retain "Underground piping" Subparagraph below only if underground piping is present and not to be insulated. If underground piping is in Project and is to be insulated, see "Outdoor, Underground, Piping Insulation Schedule" and "Underground, Field-Applied Insulation Jacket" articles below.

1. Underground piping.
2. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

Piping insulation schedules in articles below specify commonly used insulation materials and thicknesses by pipe size range for each service. LEED Prerequisite EA 2 requires that pipe insulation thickness comply with ASHRAE/IESNA 90.1 table titled "Minimum Pipe Insulation Thickness." Not all materials and thicknesses may be suitable for a specific project. Revise to suit Project after considering all parameters that impact selection. See the Evaluations for more information and guidance.

Polyisocyanurate thickness is limited to 1 inch (25 mm) to comply with a flame-spread index of 25 and a smoke-developed index of 50. Condensation control and energy efficiency are limited by thickness.

Tubular flexible elastomeric is not available in sizes of larger than NPS 6 (DN 150). Larger pipe sizes require sheets to be cut to size. Thickness is limited to 1 inch (25 mm) to comply with a flame-spread index of 25 and a smoke-developed index of 50. Condensation control and energy efficiency are limited by thickness.

Tubular polyolefin is not available in sizes larger than NPS 4 (DN 100). Larger pipe sizes require sheets to be cut to size. Thickness is limited to 1 inch (25 mm) to comply with a flame-spread index of 25 and a smoke-developed index of 50. Condensation control and energy efficiency are limited by thickness.

3.18 INDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water below 60 Deg F:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber, Preformed Pipe Insulation, Type I" "Phenolic," "Polyisocyanurate," and "Polyolefin" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**3/4 inch**] [**1 inch**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1/2 inch**] [**1 inch**] <**Insert dimension**> thick.
d. Phenolic: [**1 inch**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.
f. Polyolefin: [**3/4 inch**] [**1 inch**] <**Insert dimension**> thick.

B. Chilled Water and Brine, 40 Deg F and below:

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 3**] <**Insert pipe size**> and Smaller: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," and "Polyisocyanurate" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1 inch**] [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
c. Phenolic: [**1 inch**] [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
d. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 4 to NPS 12**] <**Insert pipe size range**>: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," and "Polyisocyanurate" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
c. Phenolic: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
d. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.

Retain "one of" option in subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 14**] <**Insert pipe size**> and Larger: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, (Preformed Pipe Insulation, Type I,) (or) (Pipe and Tank Insulation)," and "Phenolic" subparagraphs below.

a. Cellular Glass: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, [**Preformed Pipe Insulation, Type I,**] [**or**] [**Pipe and Tank Insulation**]: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
c. Phenolic: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.

C. Chilled Water and Brine, Above 40 Deg F:

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 12**] <**Insert pipe size**> and Smaller: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber Preformed Pipe Insulation, Type I," "Phenolic," "Polyisocyanurate," and "Polyolefin" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1 inch**] [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
d. Phenolic: [**1 inch**] [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.
f. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

Retain "one of" option in subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 14**] <**Insert pipe size**> and Larger: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, (Preformed Pipe Insulation, Type I,) (or) (Pipe and Tank Insulation)," and "Phenolic" subparagraphs below.

a. Cellular Glass: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber [**Preformed Pipe Insulation, Type I,**] [**or**] [**Pipe and Tank Insulation**]: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
c. Phenolic: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.

Condenser-water supply and return piping located indoors and operating in range of between 55 to 105 deg F (13 to 41 deg C) is not always insulated. If condenser-water system operates as part of a water-side economizer cycle or if Project requires condensation control, piping should be insulated.

D. Condenser-Water Supply and Return:

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 12**] <**Insert pipe size**> and Smaller: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber Preformed Pipe Insulation, Type I," "Phenolic," "Polyisocyanurate," and "Polyolefin" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1 inch**] [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
d. Phenolic: [**1 inch**] [**1-1/2 inches**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.
f. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

Retain "one of" option in subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 14**] <**Insert pipe size**> and Larger: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, (Preformed Pipe Insulation, Type I,) (or) (Pipe and Tank Insulation)," and "Phenolic" subparagraphs below.

a. Cellular Glass: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, [**Preformed Pipe Insulation, Type I**] [**or**] [**Pipe and Tank Insulation**]: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
c. Phenolic: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.

E. Heating-Hot-Water Supply and Return, 200 Deg F and Below:

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 12**] <**Insert pipe size**> and Smaller: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber Preformed Pipe, Type I," "Phenolic," and "Polyisocyanurate" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, Preformed Pipe, Type I: [**1 inch**] [**2 inches**] <**Insert dimension**> thick.
c. Phenolic: [**1 inch**] [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
d. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.

Retain "one of" option in subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 14**] <**Insert pipe size**> and Larger: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, (Preformed Pipe Insulation, Type I,) (or) (Pipe and Tank Insulation)," and "Phenolic" subparagraphs below.

a. Cellular Glass: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, [**Preformed Pipe Insulation, Type I**] [**or**] [**Pipe and Tank Insulation**]: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
c. Phenolic: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.

F. Heating-Hot-Water Supply and Return, Above 200 Deg F:

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 3/4**] <**Insert pipe size**> and Smaller: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber, Preformed Pipe Insulation, Type I" subparagraphs below.

a. Calcium Silicate: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.

Retain "one of" option in subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 1**] <**Insert pipe size**> and Larger: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber Preformed Pipe, Type I" subparagraphs below.

a. Calcium Silicate: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe, Type I: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.

In the "Steam and Steam Condensate, Boiler Blowdown, Vents, Drains(, and Safety Relief Vents) 350 Deg F (177 Deg C) and Below" Paragraph below, option is indicated, because some engineers choose to not insulate items that are not hot during normal operating conditions. Verify requirements with authorities having jurisdiction before making selection.

G. Steam and Steam Condensate, Boiler Blowdown, Vents, Drains[**, and Safety Relief Vents**] 350 Deg F and Below:

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 3/4**] <**Insert pipe size**> and Smaller: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber Preformed Pipe Insulation, Type I" subparagraphs below.

a. Calcium Silicate: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.

Retain "one of" option in subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 1**] <**Insert pipe size**> and Larger: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber, (Preformed Pipe Insulation, Type I,) (or) (Pipe and Tank Insulation)" subparagraphs below.

a. Calcium Silicate: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, [**Preformed Pipe Insulation, Type I**] [**or**] [**Pipe and Tank Insulation**]: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.

In the "Steam and Steam Condensate, Boiler Blowdown, Vents, Drains(, and Safety Relief Vents) above 350 Deg F (177 Deg C)" Paragraph below, option is indicated, because some engineers choose to not insulate items that are not hot during normal operating conditions. Verify requirements with authorities having jurisdiction before making selection.

H. Steam and Steam Condensate, Boiler Blowdown, Vents, Drains[**, and Safety Relief Vents**] Above 350 Deg F:

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 3/4**] <**Insert pipe size**> and Smaller: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber Preformed Pipe Insulation, Type I" subparagraphs below.

a. Calcium Silicate: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.

Retain "one of" option in subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 1**] <**Insert pipe size**> and Larger: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber, (Preformed Pipe Insulation, Type I,) (or) (Pipe and Tank Insulation)" subparagraphs below.

a. Calcium Silicate: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, [**Preformed Pipe Insulation, Type I**] [**or**] [**Pipe and Tank Insulation**]: [**3 inches**] [**4 inches**] <**Insert dimension**> thick.

I. Refrigerant Suction and Hot-Gas Piping:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," "Polyisocyanurate," and "Polyolefin" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1 inch**] <**Insert dimension**> thick.
d. Phenolic: [**1 inch**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.
f. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

J. Refrigerant Suction and Hot-Gas Flexible Tubing:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one of or both "Flexible Elastomeric" and "Polyolefin" subparagraphs below.

a. Flexible Elastomeric: [**2 inches**] <**Insert dimension**> thick.
b. Polyolefin: [**2 inches**] <**Insert dimension**> thick.

K. Refrigerant Liquid Piping:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber, Preformed Pipe Type I," "Phenolic," "Polyisocyanurate," and "Polyolefin" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1 inch**] <**Insert dimension**> thick.
d. Phenolic: [**1 inch**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.
f. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

L. Dual-Service Heating and Cooling, 40 to 200 Deg F:

Retain "one of" option in first subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 12**] <**Insert pipe size**> and Smaller: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," and "Polyisocyanurate" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**1 inch**] [**1-1/2 inches**] [**2 inches**] <**Insert dimension**> thick.

c. Phenolic: [**1 inch**] [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
d. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.

Retain "one of" option in subparagraph below to allow Contractor to select materials from those retained.

1. [**NPS 14**] <**Insert pipe size**> and Larger: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, (Preformed Pipe Insulation, Type I,) (or) (Pipe and Tank Insulation)," and "Phenolic" subparagraphs below.

a. Cellular Glass: [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, [**Preformed Pipe Insulation, Type I**] [**or**] [**Pipe and Tank Insulation**]: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.
c. Phenolic: [**1-1/2 inches**] [**2 inches**] [**3 inches**] <**Insert dimension**> thick.

M. Heat-Recovery Piping:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber, (Preformed Pipe Insulation, Type I,) (or) (Pipe and Tank Insulation)" "Phenolic," "Polyisocyanurate," and "Polyolefin" subparagraphs below.

a. Cellular Glass: [**1-1/2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**1 inch**] <**Insert dimension**> thick.
c. Mineral-Fiber, [**Preformed Pipe Insulation, Type I**] [**or**] [**Pipe and Tank Insulation**]: [**1 inch**] <**Insert dimension**> thick.
d. Phenolic: [**1 inch**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**1 inch**] <**Insert dimension**> thick.
f. Polyolefin: [**1 inch**] <**Insert dimension**> thick.

3.19 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

In addition to other criteria, insulate outdoor piping for freeze protection.

A. Chilled Water and Brine:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," "Polyisocyanurate," "Polyolefin," and "Polystyrene" subparagraphs below.

a. Cellular Glass: [**3 inches**] <**Insert dimension**> thick.

b. Flexible Elastomeric: [**3 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**3 inches**] <**Insert dimension**> thick.
d. Phenolic: [**2 inches**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**2 inches**] <**Insert dimension**> thick.
f. Polyolefin: [**3 inches**] <**Insert dimension**> thick.
g. Polystyrene: [**2 inches**] <**Insert dimension**> thick.

B. Condenser-Water Supply and Return:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," "Polyisocyanurate," "Polyolefin," and "Polystyrene" subparagraphs below.

a. Cellular Glass: [**2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**2 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches**] <**Insert dimension**> thick.
d. Phenolic: [**2 inches**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**2 inches**] <**Insert dimension**> thick.
f. Polyolefin: [**2 inches**] <**Insert dimension**> thick.
g. Polystyrene: [**2 inches**] <**Insert dimension**> thick.

C. Heating-Hot-Water Supply and Return, 200 Deg F and Below:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," and "Polyisocyanurate" subparagraphs below.

a. Cellular Glass: [**3 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches**] <**Insert dimension**> thick.
c. Phenolic: [**2 inches**] <**Insert dimension**> thick.
d. Polyisocyanurate: [**2 inches**] <**Insert dimension**> thick.

D. Heating-Hot-Water Supply and Return, Above 200 Deg F:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber, Preformed Pipe Insulation, Type I" subparagraphs below.

a. Calcium Silicate: [**3 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**3 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches**] <**Insert dimension**> thick.

In the "Steam and Steam Condensate(, and Safety Relief Vents), 350 Deg F (177 Deg C) and Below" Paragraph below, option is indicated, because some engineers choose to not insulate items that are not hot during normal operating conditions. Verify requirements with authorities having jurisdiction before making selection.

E. Steam and Steam Condensate[**, and Safety Relief Vents**], 350 Deg F and Below:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber, Preformed Pipe Insulation, Type I" subparagraphs below.

a. Calcium Silicate: [**4 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**4 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**3 inches**] <**Insert dimension**> thick.

In the "Steam and Steam Condensate(, and Safety Relief Vents), Above 350 Deg F (177 Deg C)" Paragraph below, option is indicated, because some engineers choose to not insulate items that are not hot during normal operating conditions. Verify requirements with authorities having jurisdiction before making selection.

F. Steam and Steam Condensate[**, and Safety Relief Vents**], Above 350 Deg F:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Calcium Silicate," "Cellular Glass," and "Mineral-Fiber, Preformed Pipe Insulation, Type I" subparagraphs below.

a. Calcium Silicate: [**5 inches**] <**Insert dimension**> thick.
b. Cellular Glass: [**5 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**4 inches**] <**Insert dimension**> thick.

G. Refrigerant Suction and Hot-Gas Piping:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," "Polyisocyanurate," "Polyolefin," and "Polystyrene" subparagraphs below.

a. Cellular Glass: [**2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**2 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches**] <**Insert dimension**> thick.
d. Phenolic: [**2 inches**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**2 inches**] <**Insert dimension**> thick.
f. Polyolefin: [**2 inches**] <**Insert dimension**> thick.
g. Polystyrene: [**2 inches**] <**Insert dimension**> thick.

H. Refrigerant Suction and Hot-Gas Flexible Tubing:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one of or both "Flexible Elastomeric" and "Polyolefin" subparagraphs below.

a. Flexible Elastomeric: [**2 inches**] <**Insert dimension**> thick.
b. Polyolefin: [**2 inches**] <**Insert dimension**> thick.

I. Refrigerant Liquid Piping:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one of or both "Flexible Elastomeric" and "Polyolefin" subparagraphs below.

a. Flexible Elastomeric: [**1 inch**] [**2 inches**] <**Insert dimension**> thick.
b. Polyolefin: [**1 inch**] [**2 inches**] <**Insert dimension**> thick.

J. Heat-Recovery Piping:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Flexible Elastomeric," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," "Polyisocyanurate," "Polyolefin," and "Polystyrene" subparagraphs below.

a. Cellular Glass: [**2 inches**] <**Insert dimension**> thick.
b. Flexible Elastomeric: [**2 inches**] <**Insert dimension**> thick.
c. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches**] <**Insert dimension**> thick.
d. Phenolic: [**2 inches**] <**Insert dimension**> thick.
e. Polyisocyanurate: [**2 inches**] <**Insert dimension**> thick.
f. Polyolefin: [**2 inches**] <**Insert dimension**> thick.
g. Polystyrene: [**2 inches**] <**Insert dimension**> thick.

K. Dual-Service Heating and Cooling:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one or more of "Cellular Glass," "Mineral-Fiber, Preformed Pipe Insulation, Type I," "Phenolic," and "Polyisocyanurate" subparagraphs below.

a. Cellular Glass: [**3 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches**] <**Insert dimension**> thick.
c. Phenolic: [**2 inches**] <**Insert dimension**> thick.
d. Polyisocyanurate: [**2 inches**] <**Insert dimension**> thick.

L. Fuel Oil Piping, Heated:

Retain "one of" option in "All Pipe Sizes" Subparagraph below to allow Contractor to select materials from those retained.

1. All Pipe Sizes: Insulation shall be[**one of**] the following:

Retain one of or both "Cellular Glass" and "Mineral-Fiber, Preformed Pipe Insulation, Type I" subparagraphs below.

a. Cellular Glass: [**2 inches**] <**Insert dimension**> thick.
b. Mineral-Fiber, Preformed Pipe Insulation, Type I: [**2 inches**] <**Insert dimension**> thick.

3.20 OUTDOOR, UNDERGROUND, PIPING INSULATION SCHEDULE

Insulation specified in this article is limited to those insulation types that have high compressive strength. Other insulation types may be considered acceptable and should be evaluated on a project basis. Cellular glass is best suited for applications of below 250 deg F (121 deg C), because of its moisture-resistant properties.

A. Insulation, for belowground piping, is specified in Section 232113.13 "Underground Hydronic Piping" and Section 336313 "Underground Steam and Condensate Distribution Piping."

B. Chilled Water, All Sizes: Cellular glass, [**2 inches**] <**Insert dimension**> thick.

C. Condenser-Water Supply and Return, All Sizes: Cellular glass, [**2 inches**] <**Insert dimension**> thick.

D. Heating-Hot-Water Supply and Return, All Sizes, 200 Deg F and Below: Cellular glass, [**3 inches**] <**Insert dimension**> thick.

E. Heating-Hot-Water Supply and Return, All Sizes, Above 200 Deg F:

Retain one of or both "Calcium Silicate" and "Cellular Glass" subparagraphs below.

1. Calcium Silicate: [**3 inches**] <**Insert dimension**> thick.
2. Cellular Glass: [**3 inches**] <**Insert dimension**> thick.

F. Steam and Steam Condensate, All Sizes, 350 Deg F and Below:

Retain one of or both "Calcium Silicate" and "Cellular Glass" subparagraphs below.

1. Calcium Silicate: [**4 inches**] <**Insert dimension**> thick.
2. Cellular Glass: [**4 inches**] <**Insert dimension**> thick.

G. Steam and Steam Condensate, All Sizes, Above 350 Deg F:

Retain one of or both "Calcium Silicate" and "Cellular Glass" subparagraphs below.

1. Calcium Silicate: [**5 inches**] <**Insert dimension**> thick.
2. Cellular Glass: [**5 inches**] <**Insert dimension**> thick.

H. Dual-Service Heating and Cooling, All Sizes, 40 to 200 Deg F: Cellular glass, [**3 inches**] <**Insert dimension**> thick.

I. Fuel Oil Piping, All Sizes, Heated: Cellular glass, [**2 inches**] <**Insert dimension**> thick.

3.21 INDOOR, FIELD-APPLIED JACKET SCHEDULE

Possible variations of jackets by location are endless. This article specifies locations in two broad categories: concealed and exposed. Revise if additional delineation is necessary.

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Concealed:

Retain one of six subparagraphs below.

1. None.
2. [**PVC**] [**PVC, Color-Coded by System**]: [**20 mils**] [**30 mils**] thick.
3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] [**0.040 inch**] thick.

4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] thick.
5. Stainless Steel, [**Type 304**] [**or**] [**Type 316**], [**Smooth No. 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch**] [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] thick.
6. <**Insert jacket type**>.

D. Piping, Exposed:

Retain one of six subparagraphs below.

1. None.
2. [**PVC**] [**PVC, Color-Coded by System**]: [**20 mils**] [**30 mils**] thick.
3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] [**0.040 inch**] thick.
4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] thick.
5. Stainless Steel, [**Type 304**] [**or**] [**Type 316**], [**Smooth No. 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch**] [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] thick.
6. <**Insert jacket type**>.

3.22 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

Possible variations of jackets by location are endless. This article specifies locations in two broad categories: concealed and exposed. Revise if additional delineation is necessary.

30-mil (0.8-mm) or heavier PVC is recommended for outdoor applications. 40-mil (1.0-mm) PVC does not comply with a flame-spread index of 25 and a smoke-developed index of 50; however, a flame-spread or smoke-developed index is not a requirement for outdoor applications.

0.024-inch (0.61-mm) or heavier aluminum is recommended for outdoor applications.

Painted aluminum increases surface emissivity and provides added chemical resistance. See the Evaluations for discussion of emissivity.

0.016-inch (0.41-mm) or heavier stainless steel is recommended for outdoor applications.

Z-shaped locking seam is recommended for metal jackets located in unprotected applications that are exposed to severe weather.

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Concealed:

Retain one of six subparagraphs below.

1. None.
2. [**PVC**] [**PVC, Color-Coded by System**]: [**20 mils**] [**30 mils**] thick.

3. Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] [**0.040 inch**] thick.
4. Painted Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] thick.
5. Stainless Steel, [**Type 304**] [**Type 316**] [**Type 304**] [**or**] [**Type 316**], [**Smooth No. 2B Finish**] [**Corrugated**] [**Stucco Embossed**]: [**0.010 inch**] [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] thick.
6. <**Insert jacket type**>.

D. Piping, Exposed:

Retain one of four subparagraphs below.

1. PVC: [**20 mils**] [**30 mils**] [**40 mils**] thick.
2. [**Painted**]Aluminum, [**Smooth**] [**Corrugated**] [**Stucco Embossed**] [**with Z-Shaped Locking Seam**]: [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] [**0.032 inch**] [**0.040 inch**] thick.
3. Stainless Steel, [**Type 304**] [**Type 316**] [**Type 304**] [**or**] [**Type 316**], [**Smooth No. 2B Finish**] [**Corrugated**] [**Stucco Embossed**] [**with Z-Shaped Locking Seam**]: [**0.010 inch**] [**0.016 inch**] [**0.020 inch**] [**0.024 inch**] thick.
4. <**Insert jacket type**>.

3.23 UNDERGROUND, FIELD-APPLIED INSULATION JACKET

A. For underground direct-buried piping applications, install underground direct-buried jacket over insulation material.

END OF SECTION 230719

SECTION 230923 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on Masterworks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on Masterworks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. DDC system for monitoring and controlling of HVAC systems.

Coordinate subparagraph below with "Control Devices for Installation by Installers" and "Control Devices for Equipment Manufacturer Factory Installation" articles.

2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.

B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 230923.13 "Energy Meters" for thermal and electric power energy meters that connect to DDC systems.
2. Section 230923.17 "Level Instruments" for liquid-level switches, sensors, and transmitters that connect to DDC systems.
3. Section 230923.22 "Position Instruments" for limit switches that connect to DDC systems.
4. Section 230923.33 "Vibration Instruments" for vibration instruments that connect to DDC systems.
5. Section 230923.43 "Weather Stations" for weather stations that connect to DDC systems.
6. Section 230993.11 "Sequence of Operations for HVAC DDC" for control sequences in DDC systems.
7. Communications Cabling:

    a. Section 260523 "Control-Voltage Electrical Power Cables" for balanced twisted pair communications cable.
    b. Section 271513 "Communications Copper Horizontal Cabling" for balanced twisted pair communications cable.
    c. Section 271523 "Communications Optical Fiber Horizontal Cabling" for optical fiber communications cable.

8. Raceways:

    a. Section 260533 "Raceways and Boxes for Electrical Systems" for raceways for low-voltage control cable.
    b. Section 270528 "Pathways for Communications Systems" for raceways for balanced twisted pair cabling and optical fiber cable.

9. Section 260553 "Identification for Electrical Systems" for identification requirements for electrical components.
10. Section 270553 "Identification for Communications Systems" for identification requirements for communications components.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. Algorithm: A logical procedure for solving a recurrent mathematical problem. A prescribed set of well-defined rules or processes for solving a problem in a finite number of steps.

B. Analog: A continuously varying signal value, such as current, flow, pressure, or temperature.

C. BACnet Specific Definitions:

1. BACnet: Building Automation Control Network Protocol, ASHRAE 135. A communications protocol allowing devices to communicate data over and services over a network.

2. BACnet Interoperability Building Blocks (BIBBs): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.
3. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.
4. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE 135, operated under direction of BACnet International.
5. PICS (Protocol Implementation Conformance Statement): Written document that identifies the particular options specified by BACnet that are implemented in a device.

D. Binary: Two-state signal where a high signal level represents ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Digital" is sometimes used interchangeably with "Binary" to indicate a two-state signal.

E. Controller: Generic term for any standalone, microprocessor-based, digital controller residing on a network, used for local or global control. Three types of controllers are indicated: Network Controller, Programmable Application Controller, and Application-Specific Controller.

F. Control System Integrator: An entity that assists in expansion of existing enterprise system and support of additional operator interfaces to I/O being added to existing enterprise system.

G. COV: Changes of value.

H. DDC System Provider: Authorized representative of, and trained by, DDC system manufacturer and responsible for execution of DDC system Work indicated.

I. Distributed Control: Processing of system data is decentralized and control decisions are made at subsystem level. System operational programs and information are provided to remote subsystems and status is reported back. On loss of communication, subsystems shall be capable of operating in a standalone mode using the last best available data.

J. DOCSIS: Data-Over Cable Service Interface Specifications.

K. E/P: Voltage to pneumatic.

L. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.

M. HLC: Heavy load conditions.

N. I/O: System through which information is received and transmitted. I/O refers to analog input (AI), binary input (BI), analog output (AO) and binary output (BO). Analog signals are continuous and represent control influences such as flow, level, moisture, pressure, and temperature. Binary signals convert electronic signals to digital pulses (values) and generally represent two-position operating and alarm status. "Digital," (DI and (DO), is sometimes used interchangeably with "Binary," (BI) and (BO), respectively.

O. I/P: Current to pneumatic.

P. LAN: Local area network.

Q. LNS: LonWorks Network Services.

R. LON Specific Definitions:

1. FTT-10: Echelon Transmitter-Free Topology Transceiver.
2. LonMark: Association comprising suppliers and installers of LonTalk products. Association provides guidelines for implementing LonTalk protocol to ensure interoperability through a standard or consistent implementation.
3. LonTalk: An open standard protocol developed by the Echelon Corporation that uses a "Neuron Chip" for communication. LonTalk is a register trademark of Echelon.
4. LonWorks: Network technology developed by Echelon.
5. Node: Device that communicates using CEA-709.1-C protocol and that is connected to a CEA-709.1-C network.
6. Node Address: The logical address of a node on the network, consisting of a Domain number, Subnet number, and Node number. "Node number" portion of an address is a number assigned to device during installation, is unique within a subnet, and is not a factory-set unique Node ID.
7. Node ID: A unique 48-bit identifier assigned at factory to each CEA-709.1-C device. Sometimes called a "Neuron ID."
8. Program ID: An identifier (number) stored in a device (usually EEPROM) that identifies node manufacturer, functionality of device (application and sequence), transceiver used, and intended device usage.
9. Standard Configuration Property Type (SCPT): Pronounced "skip-it." A standard format type maintained by LonMark International for configuration properties.
10. Standard Network Variable Type (SNVT): Pronounced "snivet." A standard format type maintained by LonMark used to define data information transmitted and received by individual nodes. "SNVT" is used in two ways. It is an acronym for "Standard Network Variable Type" and is often used to indicate a network variable itself (i.e., it can mean "a network variable of a standard network variable type").
11. Subnet: Consists of a logical grouping of up to 127 nodes, where logical grouping is defined by node addressing. Each subnet is assigned a number, which is unique within a Domain. See "Node Address."
12. TP/FT-10: Free Topology Twisted Pair network defined by CEA-709.3 and is most common media type for a CEA-709.1-C control network.
13. TP/XF-1250: High-speed, 1.25-Mbps, twisted-pair, doubly terminated bus network defined by "LonMark Interoperability Guidelines" typically used only to connect multiple TP/FT-10 networks.
14. User-Defined Configuration Property Type (UCPT): Pronounced "U-Keep-It." A Configuration Property format type that is defined by device manufacturer.
15. User-Defined Network Variable Type (UNVT): Network variable format defined by device manufacturer. UNVTs create non-standard communications that other vendors' devices may not correctly interpret and may negatively impact system operation. UNVTs are not allowed.

S. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

T. Mobile Device: A data-enabled phone or tablet computer capable of connecting to a cellular data network and running a native control application or accessing a web interface.

U. Modbus TCP/IP: An open protocol for exchange of process data.

V. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.

W. MTBF: Mean time between failures.

X. Network Controller: Digital controller, which supports a family of programmable application controllers and application-specific controllers, that communicates on peer-to-peer network for transmission of global data.

Y. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.

Z. Peer to Peer: Networking architecture that treats all network stations as equal partners.

AA. POT: Portable operator's terminal.

BB. PUE: Performance usage effectiveness.

CC. RAM: Random access memory.

DD. RF: Radio frequency.

EE. Router: Device connecting two or more networks at network layer.

FF. Server: Computer used to maintain system configuration, historical and programming database.

GG. TCP/IP: Transport control protocol/Internet protocol.

HH. UPS: Uninterruptible power supply.

II. USB: Universal Serial Bus.

JJ. User Datagram Protocol (UDP): This protocol assumes that the IP is used as the underlying protocol.

KK. VAV: Variable air volume.

LL. WLED: White light emitting diode.

1.4 PREINSTALLATION MEETINGS

Retain "Preinstallation Conference" Paragraph below if Work of this Section is extensive or complex enough to justify a conference.

A. Preinstallation Conference: Conduct conference at [**Project site**] <**Insert location**>.

If needed, insert list of conference participants not mentioned in Section 013100 "Project Management and Coordination."

1.5 ACTION SUBMITTALS

A. Multiple Submissions:

1. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.
2. Clearly identify each submittal requirement indicated and in which submission the information will be provided.
3. Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

B. Product Data: For each type of product include the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation, operation and maintenance instructions including factors effecting performance.
5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.

Subparagraphs below are only examples of products to include.

a. Workstations.
b. Servers.
c. Printers.
d. Gateways.
e. Routers.
f. Protocol analyzers.
g. DDC controllers.
h. Enclosures.
i. Electrical power devices.
j. UPS units.
k. Accessories.
l. Instruments.
m. Control dampers and actuators.
n. Control valves and actuators.
o. <**Insert product**>.

6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.

C. Software Submittal:

1. Cross-referenced listing of software to be loaded on each operator workstation, server, gateway, <**Insert product**> and DDC controller.
2. Description and technical data of all software provided, and cross-referenced to products in which software will be installed.
3. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
4. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
5. Listing and description of each engineering equation used with reference source.
6. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
7. Description of operator interface to alphanumeric and graphic programming.
8. Description of each network communication protocol.
9. Description of system database, including all data included in database, database capacity and limitations to expand database.
10. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden and system throughout.
11. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

D. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for Energy Star labeling.>
2. <Double click to insert sustainable design text for adhesives.>

E. Shop Drawings:

1. General Requirements:

   a. Include cover drawing with Project name, location, Owner, Architect, Contractor and issue date with each Shop Drawings submission.
   b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
   c. Drawings Size: <**Insert requirements**>.

2. Include plans, elevations, sections, and mounting details where applicable.
3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail means of vibration isolation and show attachments to rotating equipment.
5. Plan Drawings indicating the following:

   a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork and piping.
   b. Room names and numbers with coordinated placement to avoid interference with control products indicated.

c. Each desktop workstation, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
e. Network communication cable and raceway routing.
f. Information, drawn to scale, of <**Insert requirements**>.
g. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.

6. Schematic drawings for each controlled HVAC system indicating the following:

a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
c. A graphic showing location of control I/O in proper relationship to HVAC system.
d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.
f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays and interface to DDC controllers.
g. Narrative sequence of operation.
h. Graphic sequence of operation, showing all inputs and output logical blocks.

7. Control panel drawings indicating the following:

a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates and allocated spare space.
c. Front, rear, and side elevations and nameplate legend.
d. Unique drawing for each panel.

8. DDC system network riser diagram indicating the following:

a. Each device connected to network with unique identification for each.
b. Interconnection of each different network in DDC system.
c. For each network, indicate communication protocol, speed and physical means of interconnecting network devices, such as copper cable type, or optical fiber cable type. Indicate raceway type and size for each.
d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.

9. DDC system electrical power riser diagram indicating the following:

a. Each point of connection to field power with requirements (volts/phase//hertz/amperes/connection type) listed for each.

b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.
c. Each product requiring power with requirements (volts/phase//hertz/amperes/connection type) listed for each.
d. Power wiring type and size, race type, and size for each.

10. Monitoring and control signal diagrams indicating the following:

a. Control signal cable and wiring between controllers and I/O.
b. Point-to-point schematic wiring diagrams for each product.
c. Control signal tubing to sensors, switches and transmitters.
d. Process signal tubing to sensors, switches and transmitters.

Retain first subparagraph below for pneumatically actuated products.

e. Pneumatic main air and control signal tubing to pneumatic [**damper**] [**and**] [**valve**] actuators, pilot-positioners if applicable, and associated transducers.

11. Color graphics indicating the following:

a. Itemized list of color graphic displays to be provided.
b. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.
c. Intended operator access between related hierarchical display screens.

F. System Description:

1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.
2. Complete listing and description of each report, log and trend for format and timing and events which initiate generation.
3. System and product operation under each potential failure condition including, but not limited to, the following:

a. Loss of power.
b. Loss of network communication signal.
c. Loss of controller signals to inputs and outpoints.
d. Operator workstation failure.
e. Server failure.
f. Gateway failure.
g. Network failure
h. Controller failure.
i. Instrument failure.
j. Control damper and valve actuator failure.
k. <**Insert potential failure conditions**>.

4. Complete bibliography of documentation and media to be delivered to Owner.
5. Description of testing plans and procedures.
6. Description of Owner training.

Retain "Samples" Paragraph below for applications requiring special attention.

G. Samples:

1. For each of the following exposed product, installed in finished space for approval of selection of aesthetic characteristics:

    a. Gas instruments specified in Section 230923.16 "Gas Instruments."
    b. Moisture instruments specified in Section 230923.19 "Moisture Instruments."
    c. Motion instruments specified in Section 230923.21 "Motion Instruments."
    d. Pressure instruments specified in Section 230923.23 "Pressure Instruments."
    e. Temperature instruments specified in Section 230923.27 "Temperature Instruments."

2. <**Insert devices**>.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

H. Delegated-Design Submittal: For DDC system products and installation indicated as being delegated.

1. Supporting documentation showing DDC system design complies with performance requirements indicated, including calculations and other documentation necessary to prove compliance.
2. Schedule and design calculations for control dampers and actuators.

    a. Flow at Project design and minimum flow conditions.
    b. Face velocity at Project design and minimum airflow conditions.
    c. Pressure drop across damper at Project design and minimum airflow conditions.
    d. AMCA 500-D damper installation arrangement used to calculate and schedule pressure drop, as applicable to installation.
    e. Maximum close-off pressure.
    f. Leakage airflow at maximum system pressure differential (fan close-off pressure).
    g. Torque required at worst case condition for sizing actuator.
    h. Actuator selection indicating torque provided.
    i. Actuator signal to control damper (on, close or modulate).
    j. Actuator position on loss of power.
    k. Actuator position on loss of control signal.

3. Schedule and design calculations for control valves and actuators.

    a. Flow at Project design and minimum flow conditions.
    b. Pressure-differential drop across valve at Project design flow condition.
    c. Maximum system pressure-differential drop (pump close-off pressure) across valve at Project minimum flow condition.
    d. Design and minimum control valve coefficient with corresponding valve position.
    e. Maximum close-off pressure.
    f. Leakage flow at maximum system pressure differential.
    g. Torque required at worst case condition for sizing actuator.
    h. Actuator selection indicating torque provided.

i. Actuator signal to control damper (on, close or modulate).
j. Actuator position on loss of power.
k. Actuator position on loss of control signal.

4. Schedule and design calculations for selecting flow instruments.

a. Instrument flow range.
b. Project design and minimum flow conditions with corresponding accuracy, control signal to transmitter and output signal for remote control.
c. Extreme points of extended flow range with corresponding accuracy, control signal to transmitter and output signal for remote control.
d. Pressure-differential loss across instrument at Project design flow conditions.
e. Where flow sensors are mated with pressure transmitters, provide information for each instrument separately and as an operating pair.

1.6 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings:

1. Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

a. Product installation location shown in relationship to room, duct, pipe and equipment.
b. Structural members to which products will be attached.
c. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices and other installed devices.
d. Size and location of wall access panels for products installed behind walls and requiring access.

2. Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

a. Ceiling components.
b. Size and location of access panels for products installed above inaccessible ceiling assemblies and requiring access.
c. Items penetrating finished ceiling including the following:

1) Lighting fixtures.
2) Air outlets and inlets.
3) Speakers.
4) Sprinklers.
5) Access panels.

6) Motion sensors.
7) Pressure sensors.
8) Temperature sensors and other DDC control system instruments.
9) <**Insert item**>.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

B. Qualification Data:

1. Systems Provider Qualification Data:

a. Resume of project manager assigned to Project.
b. Resumes of application engineering staff assigned to Project.
c. Resumes of installation and programming technicians assigned to Project.
d. Resumes of service technicians assigned to Project.
e. Brief description of past project including physical address, floor area, number of floors, building system cooling and heating capacity and building's primary function.
f. Description of past project DDC system, noting similarities to Project scope and complexity indicated.
g. Names of staff assigned to past project that will also be assigned to execute work of this Project.
h. Owner contact information for past project including name, phone number, and e-mail address.
i. Contractor contact information for past project including name, phone number, and e-mail address.
j. Architect[**and Engineer**] contact information for past project including name, phone number, and e-mail address.

2. Manufacturer's qualification data.
3. Testing agency's qualifications data.

Retain "Welding certificates" Paragraph below if retaining "Welding Qualifications" Paragraph in "Quality Assurance" Article.

C. Welding certificates.

Retain "Product Certificates" Paragraph below to require submittal of product certificates from manufacturers.

D. Product Certificates:

Retain one of three subparagraphs below. Retain first subparagraph if compliance with ASHRAE 135 is required; retain second if LonWorks is required.

1. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with ASHRAE 135.
2. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with LonWorks.

Retain subparagraph below to require submittal of product certificates from manufacturers.

3. <**Insert list of products**>.

E. Product Test Reports: For each product that requires testing to be performed by [**manufacturer**] [**manufacturer and witnessed by a qualified testing agency**] [**a qualified testing agency**].

Retain "Preconstruction Test Reports" Paragraph below if specifying preconstruction testing in "Preconstruction Testing" Article as Contractor's responsibility.

F. Preconstruction Test Reports: For each separate test performed.

G. Source quality-control reports.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

H. Field quality-control reports.

I. Sample Warranty: For manufacturer's warranty.

1.7 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

   a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
   b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
   c. As-built versions of submittal Product Data.
   d. Names, addresses, e-mail addresses and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
   e. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control and changing set points and variables.
   f. Programming manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
   g. Engineering, installation, and maintenance manuals that explain how to:

      1) Design and install new points, panels, and other hardware.
      2) Perform preventive maintenance and calibration.
      3) Debug hardware problems.
      4) Repair or replace hardware.

h. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.
i. Backup copy of graphic files, programs, and database on electronic media such as DVDs.
j. List of recommended spare parts with part numbers and suppliers.
k. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
l. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
m. Licenses, guarantees, and warranty documents.
n. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
o. Owner training materials.

1.8 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Include product manufacturers' recommended parts lists for proper product operation over [**four**] <**Insert time period**>-year period following warranty period. Parts list shall be indicated for each year.

Retain first paragraph below for product parts inventory over an extended operating period.

C. Furnish parts, as indicated by manufacturer's recommended parts list, for product operation during [**one**] [**two**] <**Insert time period**>-year period following warranty period.

Retain paragraph below for spare product inventory.

D. Furnish quantity indicated of matching product(s) in Project inventory for each unique size and type of following:

Subparagraphs below are examples only of extra materials that may be required.

1. Network Controller: [**One**] <**Insert quantity**>.
2. Programmable Application Controller: [**One**] <**Insert quantity**>.
3. Application-Specific Controller: [**One**] <**Insert quantity**>.
4. [**Room**]Carbon Dioxide Sensor and Transmitter: [**One**] <**Insert quantity**>.
5. [**Room**]Moisture Sensor and Transmitter: [**One**] <**Insert quantity**>.
6. [**Room**]Pressure Sensor and Transmitter: [**One**] <**Insert quantity**>.
7. [**Room**]Temperature Sensor[**and Transmitter**]: [**One**] <**Insert quantity**>.
8. General-Purpose Relay: [**One**] <**Insert quantity**>.
9. Multifunction Time-Delay Relay: [**One**] <**Insert quantity**>.
10. Latching Relay: [**One**] <**Insert quantity**>.
11. Current-Sensing Relay: [**One**] <**Insert quantity**>.
12. Combination On-Off Status Sensor and On-Off Relay: [**One**] <**Insert quantity**>.
13. Transformer: [**One**] <**Insert quantity**>.

14. DC Power Supply: [**One**] <**Insert quantity**>.
15. Supply of [**20**] <**Insert number**> percent spare optical fiber cable splice organizer cabinets for several re-terminations.
16. <**Insert product**>.

1.9 QUALITY ASSURANCE

A. DDC System Manufacturer Qualifications:

1. Nationally recognized manufacturer of DDC systems and products.
2. DDC systems with similar requirements to those indicated for a continuous period of [**five**] [**10**] <**Insert number**> years within time of bid.
3. DDC systems and products that have been successfully tested and in use on at least [**three**] [**five**] <**Insert number**> past projects.
4. Having complete published catalog literature, installation, operation and maintenance manuals for all products intended for use.
5. Having full-time in-house employees for the following:

    a. Product research and development.
    b. Product and application engineering.
    c. Product manufacturing, testing and quality control.
    d. Technical support for DDC system installation training, commissioning and troubleshooting of installations.
    e. Owner operator training.

B. DDC System Provider Qualifications:

1. Authorized representative of, and trained by, DDC system manufacturer.
2. In-place facility located within <**Insert distance**> of Project.
3. Demonstrated past experience with installation of DDC system products being installed for period within [**three**] [**five**] <**Insert number**> consecutive years before time of bid.
4. Demonstrated past experience on [**five**] <**Insert number**> projects of similar complexity, scope and value.
5. Each person assigned to Project shall have demonstrated past experience.
6. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
7. Service and maintenance staff assigned to support Project during warranty period.
8. Product parts inventory to support on-going DDC system operation for a period of not less than [**5**] <**Insert number**> years after Substantial Completion.
9. DDC system manufacturer's backing to take over execution of Work if necessary to comply with requirements indicated. Include Project-specific written letter, signed by manufacturer's corporate officer, if requested.

Retain "Testing Agency Qualifications" Paragraph below if Contractor selects testing agency or if Contractor is required to provide services of a qualified testing agency in "Field Quality Control" Article. Qualification requirements are in addition to those specified in Section 014000 "Quality Requirements."

C. Testing Agency Qualifications: Member company of NETA.

1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

Retain "Welding Qualifications" Paragraph below if shop or field welding is required. If retaining, also retain "Welding certificates" Paragraph in "Informational Submittals" Article.

D. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."
3. AWS D1.3/D1.3M, "Structural Welding Code - Sheet Steel."
4. AWS D1.4/D1.4M, "Structural Welding Code - Reinforcing Steel."

E. Pipe and Pressure-Vessel Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

Retain "Mockups" Paragraph below for applications with stringent requirements.

F. Mockups: Build mockups to verify selections made under Sample submittals, to demonstrate aesthetic effects, and to set quality standards for materials and products and for fabrication and installation.

Retain one of first two, or both, subparagraphs below.

1. Build mockups of completed installation where products are exposed to view and are located in areas with aesthetic requirements that warrant special attention, including the following spaces:

In first subparagraph below, list specific areas requiring mockups, such as main lobbies, executive offices, conference rooms, and board rooms.

a. <**Insert specific locations for mockups**>.

Indicate portion of mockup on Drawings.

2. Build mockups of completed installation for areas indicated on Drawings.
3. Approval of mockups does not constitute approval of deviations from Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.

1.10 PRECONSTRUCTION TESTING

Retain this article for preconstruction testing. Project-specific preconstruction testing of assemblies can be expensive but may be the best means of proving that performance requirements are met.

A. Preconstruction Testing Service: [**Owner will engage**] [**Engage**] a qualified testing agency to perform preconstruction testing on field mockups.

Retain first subparagraph below if configuration of assemblies are not indicated on Drawings.

1. <**Insert configurations of assemblies**>.
2. Include test assemblies representative of proposed materials and construction.
3. Build mockup at testing agency facility using personnel, materials, and methods of construction that will be used at Project site.

4. Notify Architect [**seven**] <**Insert number**> days in advance of dates and times of tests.

B. Preconstruction Testing: Performed by a qualified testing agency on manufacturer's standard assemblies.

Describe Project-specific preconstruction testing requirements.

1. <**Insert preconstruction testing requirements**>.

1.11 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.

1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.

a. Install updates only after receiving Owner's written authorization.

3. Warranty service shall occur during normal business hours and commence within [**16**] [**24**] <**Insert number**> hours of Owner's warranty service request.

Verify available warranties and warranty periods.

4. Warranty Period: [**Two**] <**Insert number**> year(s) from date of Substantial Completion.

a. For Gateway: [**Two**] [**Three**] <**Insert number**>-year parts and labor warranty for each.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 DDC SYSTEM MANUFACTURERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.2 DDC SYSTEM DESCRIPTION

A. Microprocessor-based monitoring and control including analog/digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices to achieve a set of predefined conditions.

1. DDC system shall consist of a[**high-speed,**] peer-to-peer network of distributed DDC controllers[**, other network devices**], operator interfaces, and software.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 WEB ACCESS

Retain this article to require Web access to DDC system.

In paragraph below, retain one or both "Web based" and "Web compatible" options. See Evaluations for discussion. Consult manufacturers about Web-access capabilities of their DDC system offerings. Limiting to only one method of Web access may exclude some manufacturers.

A. DDC system shall be [**Web based**] [**or**] [**Web compatible**].

Retain "Web-Based Access to DDC System" Subparagraph below if retaining "Web based" option in paragraph above.

1. Web-Based Access to DDC System:

a. DDC system software shall be based on server thin-client architecture, designed around open standards of Web technology. DDC system server shall be accessed using a Web browser over DDC system network, using Owner's LAN, and remotely over Internet[**through Owner's LAN**].

b. Intent of thin-client architecture is to provide operators complete access to DDC system via a Web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.

c. Web access shall be password protected.

Retain "Web-Compatible Access to DDC System" Subparagraph below if retaining "Web compatible" option in paragraph above.

2. Web-Compatible Access to DDC System:

a. [**Workstation**] [**and**] [**or**] [**server**] shall perform overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.

b. DDC system shall support Web browser access to building data. Operator using a standard Web browser shall be able to access control graphics and change adjustable set points.

c. Web access shall be password protected.

2.4 PERFORMANCE REQUIREMENTS

Retain one of two "Delegated Design" paragraphs below if Contractor is required to assume responsibility for design.

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design DDC system to satisfy requirements indicated.

B. Delegated Design: Engage a qualified professional to design DDC system to satisfy requirements indicated.

1. System Performance Objectives:

a. DDC system shall manage HVAC systems.
b. DDC system control shall operate HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
c. DDC system shall respond to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
d. DDC system shall operate while unattended by an operator and through operator interaction.
e. DDC system shall record trends and transaction of events and produce report information such as performance, energy, occupancies, and equipment operation.

C. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.

1. Flame-Spread Index: [**25**] <**Insert value**> or less.
2. Smoke-Developed Index: [**50**] <**Insert value**> or less.

D. DDC System Speed:

1. Response Time of Connected I/O:

First option in subparagraphs below is taken from ASHRAE's Guideline 13.

a. AI point values connected to DDC system shall be updated at least every [**five**] [**two**] seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
b. BI point values connected to DDC system shall be updated at least every [**five**] [**two**] <**Insert number**> seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
c. AO points connected to DDC system shall begin to respond to controller output commands within [**two**] [**one**] second(s). Global commands shall also comply with this requirement.
d. BO point values connected to DDC system shall respond to controller output commands within [**two**] [**one**] <**Insert number**> second(s). Global commands shall also comply with this requirement.

2. Display of Connected I/O:

a. Analog point COV connected to DDC system shall be updated and displayed at least every [**10**] [**five**] <**Insert number**> seconds for use by operator.
b. Binary point COV connected to DDC system shall be updated and displayed at least every [**10**] [**five**] <**Insert number**> seconds for use by operator.
c. Alarms of analog and digital points connected to DDC system shall be displayed within [**45**] [**30**] [**15**] <**Insert number**> seconds of activation or change of state.
d. Graphic display refresh shall update within [**eight**] [**four**] <**Insert number**> seconds.
e. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate indicated.

E. Network Bandwidth: Design each network of DDC system to include at least [**30**] <**Insert number**> percent available spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions.

Retain "DDC System Data Storage" Paragraph below to provide DDC system data archived storage over an extended operating period.

F. DDC System Data Storage:

1. Include capability to archive not less than [**24**] [**48**] [**60**] <**Insert number**> consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends and other information indicated.
2. Local Storage:

a. Provide [**server**] [**workstation**] with data storage indicated. Server(s) shall use IT industry standard database platforms and be capable of functions described in "DDC Data Access" Paragraph.

3. Cloud Storage:

a. Provide [**application-based**] [**and**] [**web browser**] interfaces to configure, upload, download, and manage data, and service plan with storage adequate to store all data for term indicated. Cloud storage shall use IT industry standard database platforms and be capable of functions described in "DDC Data Access" Paragraph.

Retain "DDC Data Access" Paragraph below for systems using local data storage or systems that store information locally and on the cloud. Change terminology as required. Coordinate with "Servers" Article in Part 2.

G. DDC Data Access:

1. When logged into the system, operator shall be able to also interact with any DDC controller connected to DDC system as required for functional operation of DDC system.
2. System(s) shall be used for application configuration; for archiving, reporting and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.

H. Future Expandability:

1. DDC system size shall be expandable to an ultimate capacity of at least [**two**] [**three**] [**four**] <**Insert number**> times total I/O points indicated.
2. Additional DDC controllers, I/O and associated wiring shall be all that is needed to achieve ultimate capacity. Initial network infrastructure shall be designed and installed to support ultimate capacity.
3. Operator interfaces installed initially shall not require hardware and software additions and revisions for ultimate capacity.

I. Input Point Displayed Accuracy: Input point displayed values shall meet following end-to-end overall system accuracy, including errors associated with meter, sensor, transmitter, lead wire or cable, and analog to digital conversion.

Coordinate values used in subparagraphs below with accuracy of instruments specified in related sections. Values below cannot be better than other values used elsewhere.

1. Energy:

   a. Thermal: Within [**5**] [**3**] [**1**] <**Insert number**> percent of reading.
   b. Electric Power: Within [**1**] <**Insert number**> percent of reading.
   c. Requirements indicated on Drawings for meters not supplied by utility.

2. Flow:

   a. Air: Within [**5**] [**2**] <**Insert number**> percent of design flow rate.
   b. Air (Terminal Units): Within [**10**] [**5**] <**Insert number**> percent of design flow rate.
   c. Water: Within [**2**] [**5**] <**Insert number**> percent of design flow rate.
   d. Steam: Within [**5**] <**Insert number**> percent of design flow rate.

3. Gas:

   a. Carbon Dioxide: Within [**50**] <**Insert value**> ppm.
   b. Carbon Monoxide: Within [**5**] <**Insert number**> percent of reading.
   c. Oxygen: Within [**5**] <**Insert number**> percent of reading.
   d. Refrigerant: Within [**50**] <**Insert value**> ppm.

4. Moisture (Relative Humidity):

   a. Air: Within [**5**] [**2**] <**Insert number**> percent RH.
   b. Space: Within [**5**] [**2**] <**Insert number**> percent RH.
   c. Outdoor: Within [**5**] [**2**] <**Insert number**> percent RH.

5. Level: Within [**5**] [**2**] <**Insert number**> percent of reading.
6. Pressure:

   a. Air, Ducts and Equipment: [**1**] [**0.5**] <**Insert number**> percent of instrument [**range**] [**span**].
   b. Space: Within [**1**] [**0.5**] [**0.25**] <**Insert number**> percent of instrument [**range**] [**span**].

c. Water: Within [**1**] [**0.5**] [**0.25**] <**Insert number**> percent of instrument [**range**] [**span**].
d. Steam: Within [**1**] [**0.5**] [**0.25**] <**Insert number**> percent of instrument [**range**] [**span**].

7. Speed: Within [**10**] [**5**] <**Insert number**> percent of reading.
8. Temperature, Dew Point:

a. Air: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
b. Space: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
c. Outdoor: Within [**3 deg F**] [**2 deg F**] <**Insert value**>.

9. Temperature, Dry Bulb:

a. Air: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
b. Space: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
c. Outdoor: Within [**2 deg F**] [**1 deg F**] <**Insert value**>.
d. Chilled Water: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
e. Condenser Water: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
f. Heating Hot Water: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
g. Energy Recovery Runaround Liquid: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
h. Steam: Within [**2 deg F**] [**1 deg F**] <**Insert value**>.
i. Temperature Difference: Within [**0.25 deg F**] <**Insert value**>.
j. <**Insert system**>.
k. Other Temperatures Not Indicated: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.

10. Temperature, Wet Bulb:

a. Air: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
b. Space: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
c. Outdoor: Within [**2 deg F**] [**1 deg F**] <**Insert value**>.

11. Vibration: Within [**5**] [**10**] <**Insert number**> percent of reading.

J. Precision of I/O Reported Values: Values reported in database and displayed shall have following precision:

1. Current:

a. Milliamperes: Nearest 1/100th of a milliampere.
b. Amperes: Nearest 1/10th of an ampere up to 100 A; nearest ampere for 100 A and more.

2. Energy:

a. Electric Power:

1) Rate (Watts): Nearest 1/10th of a watt through 1000 W.
2) Rate (Kilowatts): Nearest 1/10th of a kilowatt through 1000 kW; nearest kilowatt above 1000 kW.

3) Usage (Kilowatt-Hours): Nearest kilowatt through 10,000 kW; nearest 10 kW between 10,000 and 100,000 kW; nearest 100 kW for above 100,000 kW.

b. Thermal, Rate:

1) Heating: For Btu/h, nearest Btu/h up to 1000 Btu/h; nearest 10 Btu/h between 1000 and 10,000 Btu/h; nearest 100 Btu/h for above 10,000 Btu/h. For Mbh, round to nearest Mbh up to 1000 Mbh; nearest 10 Mbh between 1000 and 10,000 Mbh; nearest 100 Mbh above 10,000 Mbh.
2) Cooling: For tons, nearest ton up to 1000 tons; nearest 10 tons between 1000 and 10,000 tons; nearest 100 tons above 10,000 tons.

c. Thermal, Usage:

1) Heating: For Btu, nearest Btu up to 1000 Btu; nearest 10 Btu between 1000 and 10,000 Btu; nearest 100 Btu for above 10,000 Btu. For Mbtu, round to nearest Mbtu up to 1000 Mbtu; nearest 10 Mbtu between 1000 and 10,000 Mbtu; nearest 100 Mbtu above 10,000 Mbtu.
2) Cooling: For ton-hours, nearest ton-hours up to 1000 ton-hours; nearest 10 ton-hours between 1000 and 10,000 ton-hours; nearest 100 tons above 10,000 tons.

3. Flow:

a. Air: Nearest 1/10th of a cfm through 100 cfm; nearest cfm between 100 and 1000 cfm; nearest 10 cfm between 1000 and 10,000 cfm; nearest 100 cfm above 10,000 cfm.
b. Water: Nearest 1/10th gpm through 100 gpm; nearest gpm between 100 and 1000 gpm; nearest 10 gpm between 1000 and 10,000 gpm; nearest 100 gpm above 10,000 gpm.
c. Steam: Nearest 1/10th lb/hr through 100 lbs/hr; nearest lbs/hr between 100 and 1000 lbs/hr; nearest 10 lbs/hr above 1000 lbs/hr.

4. Gas:

a. Carbon Dioxide (ppm): Nearest ppm.
b. Carbon Monoxide (ppm): Nearest ppm.
c. Oxygen (Percentage): Nearest 1/10th of 1 percent.
d. Refrigerant (ppm): Nearest ppm.

5. Moisture (Relative Humidity):

a. Relative Humidity (Percentage): Nearest 1 percent.

6. Level: Nearest 1/100th of an inch through 10 inches; nearest 1/10 of an inch between 10 and 100 inches; nearest inch above 100 inches.
7. Speed:

a. Rotation (rpm): Nearest 1 rpm.

b. Velocity: Nearest 1/10th fpm through 100 fpm; nearest fpm between 100 and 1000 fpm; nearest 10 fpm above 1000 fpm.

8. Position, Dampers and Valves (Percentage Open): Nearest 1 percent.
9. Pressure:

a. Air, Ducts and Equipment: Nearest 1/10th in. w.c..
b. Space: Nearest 1/100th in. w.c..
c. Steam: Nearest 1/10th psig through 100 psig; nearest psig above 100 psig.
d. Water: Nearest 1/10 psig through 100 psig; nearest psig above 100 psig.

10. Temperature:

a. Air, Ducts and Equipment: Nearest 1/10th of a degree.
b. Outdoor: Nearest degree.
c. Space: Nearest 1/10th of a degree.
d. Chilled Water: Nearest 1/10th of a degree.
e. Condenser Water: Nearest 1/10th of a degree.
f. Heating Hot Water: Nearest degree.
g. Heat Recovery Runaround: Nearest 1/10th of a degree.
h. Steam: Nearest degree.

11. Vibration: Nearest 1/10th in/s.
12. Voltage: Nearest 1/10 volt up to 100 V; nearest volt above 100 V.

K. Control Stability: Control variables indicated within the following limits:

Coordinate values used in subparagraphs below with values used in "Input Point Displayed Accuracy" Paragraph in this article and with accuracy of instruments specified in related sections. Values below cannot be better than other values used elsewhere.

1. Flow:

a. Air, Ducts and Equipment, except Terminal Units: Within [**5**] [**2**] <**Insert number**> percent of design flow rate.
b. Air, Terminal Units: Within [**10**] [**5**] <**Insert number**> percent of design flow rate.
c. Water: Within [**2**] [**5**] <**Insert number**> percent of design flow rate.
d. Steam: Within [**5**] <**Insert number**> percent of design flow rate.

2. Gas:

a. Carbon Dioxide: Within [**50**] <**Insert value**> ppm.
b. Carbon Monoxide: Within [**5**] <**Insert number**> percent of reading.
c. Oxygen: Within [**5**] <**Insert number**> percent of reading.

3. Moisture (Relative Humidity):

a. Air: Within [**5**] [**2**] <**Insert number**> percent RH.
b. Space: Within [**5**] [**2**] <**Insert number**> percent RH.
c. Outdoor: Within [**5**] [**2**] <**Insert number**> percent RH.

4. Level: Within [**5**] [**2**] <**Insert number**> percent of reading.
5. Pressure:

    a. Air, Ducts and Equipment: [**1**] [**0.5**] <**Insert number**> percent of instrument [**range**] [**span**].
    b. Space: Within [**1**] [**0.5**] [**0.25**] <**Insert number**> percent of instrument [**range**] [**span**].
    c. Water: Within [**1**] [**0.5**] [**0.25**] <**Insert number**> percent of instrument [**range**] [**span**].
    d. Steam: Within [**1**] [**0.5**] [**0.25**] <**Insert number**> percent of instrument [**range**] [**span**].

6. Temperature, Dew Point:

    a. Air: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
    b. Space: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.

7. Temperature, Dry Bulb:

    a. Air: Within [**2 deg F**] [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
    b. Space: Within [**2 deg F**] [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
    c. Chilled Water: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
    d. Condenser Water: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
    e. Heating Hot Water: Within [**2 deg F**] [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
    f. Energy Recovery Runaround Liquid: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
    g. <**Insert system**>.

8. Temperature, Wet Bulb:

    a. Air: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.
    b. Space: Within [**1 deg F**] [**0.5 deg F**] <**Insert value**>.

L. Environmental Conditions for Controllers, Gateways, and Routers:

1. Products shall operate without performance degradation under ambient environmental temperature, pressure and humidity conditions encountered for installed location.

    a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by product and application.

2. Products shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Products not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:

    a. Outdoors, Protected: [**Type 2**] [**Type 3**] [**Type 12**] <**Insert type**>.
    b. Outdoors, Unprotected: [**Type 4**] [**Type 4X**].

c. Indoors, Heated with Filtered Ventilation: [**Type 1**] [**Type 2**] <**Insert type**>.
d. Indoors, Heated with Non-Filtered Ventilation: [**Type 2**] [**Type 12**] <**Insert type**>.
e. Indoors, Heated and Air Conditioned: [**Type 1**] <**Insert type**>.
f. Mechanical Equipment Rooms:

1) Chiller and Boiler Rooms: [**Type 12**] [**Type 4**] [**Type 4X**] <**Insert type**>.
2) Air-Moving Equipment Rooms: [**Type 1**] [**Type 2**] [**Type 12**] <**Insert type**>.

g. Localized Areas Exposed to Washdown: [**Type 4**] [**Type 4X**] <**Insert type**>.
h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: [**Type 2**] [**Type 3**] [**Type 12**] <**Insert type**>.
i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: [**Type 4**] [**Type 4X**] <**Insert type**>.
j. Hazardous Locations: Explosion-proof rating for condition.
k. <**Insert location and enclosure requirements**>.

M. Environmental Conditions for Instruments and Actuators:

1. Instruments and actuators shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.

a. If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated[**, cooled**] and ventilated as required by instrument and application.

2. Instruments, actuators and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments and actuators not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:

a. Outdoors, Protected: [**Type 2**] [**Type 3**] [**Type 12**] <**Insert type**>.
b. Outdoors, Unprotected: [**Type 4**] [**Type 4X**].
c. Indoors, Heated with Filtered Ventilation: [**Type 1**] [**Type 2**] <**Insert type**>.
d. Indoors, Heated with Non-Filtered Ventilation: [**Type 2**] [**Type 12**] <**Insert type**>.
e. Indoors, Heated and Air-conditioned: [**Type 1**] <**Insert type**>.
f. Mechanical Equipment Rooms:

1) Chiller and Boiler Rooms: [**Type 12**] [**Type 4**] [**Type 4X**] <**Insert type**>.
2) Air-Moving Equipment Rooms: [**Type 1**] [**Type 2**] [**Type 12**] <**Insert type**>.

g. Localized Areas Exposed to Washdown: [**Type 4**] [**Type 4X**] <**Insert type**>.
h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: [**Type 2**] [**Type 3**] [**Type 12**] <**Insert type**>.
i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: [**Type 4**] [**Type 4X**] <**Insert type**>.

j. Hazardous Locations: Explosion-proof rating for condition.
k. <**Insert location and enclosure requirements**>.

Retain "DDC System Reliability" Paragraph below for projects with critical reliability requirements.

N. DDC System Reliability:

1. Design, install and configure DDC controllers, [**gateways,**] [**routers,**] [**and**] <**Insert product**> to yield a MTBF of at least [**40,000**] [**20,000**] <**Insert number**> hours, based on a confidence level of at least [**90**] <**Insert number**> percent. MTBF value shall include any failure for any reason to any part of products indicated.
2. If required to comply with MTBF indicated, include DDC system and product redundancy to maintain DCC system, and associated systems and equipment that are being controlled, operational and under automatic control.
3. Critical systems and equipment that require a higher degree of DDC system redundancy than MTBF indicated shall be indicated on Drawings.

Retain "Electric Power Quality" Paragraph below for applications requiring additional protection.

O. Electric Power Quality:

1. Power-Line Surges:

a. Protect [**susceptible**]DDC system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.
b. Do not use fuses for surge protection.
c. Test protection in the normal mode and in the common mode, using the following two waveforms:

1) 10-by-1000-mic.sec. waveform with a peak voltage of 1500 V and a peak current of 60 A.
2) 8-by-20-mic.sec. waveform with a peak voltage of 1000 V and a peak current of 500 A.

2. Power Conditioning:

a. Protect [**susceptible**]DDC system products connected to ac power circuits from irregularities and noise rejection. Characteristics of power-line conditioner shall be as follows:

1) At 85 percent load, output voltage shall not deviate by more than plus or minus 1 percent of nominal when input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.
2) During load changes from zero to full load, output voltage shall not deviate by more than plus or minus 3 percent of nominal.
3) Accomplish full correction of load switching disturbances within five cycles, and 95 percent correction within two cycles of onset of disturbance.
4) Total harmonic distortion shall not exceed 3-1/2 percent at full load.

3. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition.

P. Backup Power Source:

1. HVAC systems and equipment served by a backup power source shall have associated DDC system products that control such systems and equipment also served from a backup power source.

Retain "UPS" Paragraph below for applications requiring uninterrupted power.

Q. UPS:

1. DDC system products powered by UPS units shall include the following:

Five subparagraphs below are examples only for equipment that should be provided with UPS.

a. Desktop workstations.
b. Printers.
c. Servers.
d. Gateways.
e. DDC controllers[**, except application-specific controllers**].

2. DDC system instruments and actuators powered by UPS units shall include the following:

a. Instruments associated with the following systems controlled by DDC system:

1) <**Insert list of systems**>.

b. Dampers and actuators associated with the following systems controlled by DDC system:

1) <**Insert list of systems**>.

c. Valves and actuators associated with the following systems controlled by DDC system:

1) <**Insert list of systems**>.

Retain "Continuity of Operation after Electric Power Interruption" Paragraph below for applications with systems and equipment connected to backup power systems that must remain operational without operator intervention. Coordinate requirement with other sections.

R. Continuity of Operation after Electric Power Interruption:

1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.5 PANEL-MOUNTED, MANUAL OVERRIDE SWITCHES

Retain "Manual Override of Control Dampers" Paragraph below to provide manual override capability for control dampers.

A. Manual Override of Control Dampers:

1. Include panel-mounted, two-position, selector switch for each automatic control damper being controlled by DDC controller.
2. Label each switch with damper designation served by switch.
3. Label switch positions to indicate either "Manual" or "Auto" control signal to damper.
4. With switch in "Auto" position signal to control damper actuator shall be control loop output signal from DDC controller.
5. With switch in "Manual" position, signal to damper actuator shall be controlled at panel with either an integral or separate switch to include local control.

   a. For Binary Control Dampers: Manual two-position switch shall have "Close" and "Open" switch positions indicated. With switch in "Close" position, damper shall close. With switch in "Open" position, damper shall open.
   b. For Analog Control Dampers: A gradual switch shall have "Close" and "Open" switch limits indicated. Operator shall be able to rotate switch knob to adjust damper to any position from close to open.

6. DDC controller shall monitor and report position of each manual override selector switch. With switch placed in "manual" position, DDC controller shall signal an override condition to alert operator that damper is under manual, not automatic, control.

Retain first subparagraph below to require override independent of DDC controller. Some manufacturers offer manual override feature integral to DDC controller, thus making the manual override feature more affordable. Standalone manual override switches will dramatically increase cost of manual override feature.

7. Configure manual override switches to allow operator to manually operate damper while at panel without DDC controller [**installed**] [**and**] [**operational**].
8. Terminal equipment including [**VAV units,**] [**fan-coil units,**] [**and**] [**unit heaters**] do not require manual override unless otherwise indicated by sequence of operation.

Retain "Manual Override of Control Valves" Paragraph below to provide manual override capability for control valves.

B. Manual Override of Control Valves:

1. Include panel-mounted, two-position, selector switch for each automatic control valve being controlled by a DDC controller.
2. Label each switch with valve designation served by switch.
3. Label switch positions to indicate either "Manual" or "Auto" control signal to valve.
4. With switch in "Auto" position, signal to control-valve actuator shall be a control loop output signal from DDC controller.
5. With switch in "Manual" position, signal to valve actuator shall be controlled at panel with either an integral or a separate switch to include local control.

a. For Binary Control Dampers: Manual two-position switch shall have "Close" and "Open" switch positions indicated. With switch in "Close" position, damper shall close. With switch in "Open" position, damper shall open.
b. For Analog Control Dampers: A gradual switch shall have "Open" and "Close" switch limits indicated. Operator shall be able to rotate switch knob to adjust damper to any position from close to open.

6. DDC controller shall monitor and report position of each manual override selector switch. With switch placed in "manual" position, DDC controller shall signal an override condition to alert operator that valve is under manual, not automatic, control.

Retain first subparagraph below to require override independent of DDC controller. Some manufacturers offer manual override feature integral to DDC controller, thus making the manual override feature more affordable. Standalone manual override switches will dramatically increase cost of manual override feature.

7. Configure manual override switches to allow operator to manually operate valve while at panel without DDC controller [**installed**] [**and**] [**operational**].
8. Terminal equipment including [**VAV units,**] [**fan-coil units,**] [**and**] [**unit heaters**] do not require manual override unless otherwise indicated by sequence of operation.

2.6 SYSTEM ARCHITECTURE

A. System architecture shall consist of no more than [**two**] [**or**] [**three**] <**Insert number**> levels of LANs.

1. Level one LAN shall connect network controllers and operator workstations.
2. [**Level one**] [**or**] [**Level two**] LAN shall connect programmable application controllers to other programmable application controllers, and to network controllers.
3. [**Level two**] [**or**] [**Level three**] LAN shall connect application-specific controllers to programmable application controllers and network controllers.
4. [**Level two**] [**or**] [**Level three**] LAN shall connect application-specific controllers to application-specific controllers.

Coordinate requirements in "Minimum Data Transfer and Communication Speed" Paragraph below with "Networks" Article to ensure that speed requirements retained for a project can be achieved by networks retained for a project.

B. Minimum Data Transfer and Communication Speed:

In first subparagraph below, retain "100" or "10" option for Ethernet networks. Retain "2.5" option for ATA 878.1 networks. Retain "1.25" option for CEA-709.1-C networks.

1. LAN Connecting Operator Workstations and Network Controllers: [**100**] [**10**] [**2.5**] [**1.25**] <**Insert value**> Mbps.
2. LAN Connecting Programmable Application Controllers: [**1000**] [**100**] <**Insert value**> kbps.
3. LAN Connecting Application-Specific Controllers: [**115,000**] [**76,800**] [**38,400**] [**19,200**] <**Insert value**> bps.

C. DDC system shall consist of dedicated[**and separated**] LANs that are not shared with other building systems and tenant data and communication networks.

D. System architecture shall be modular and have inherent ability to expand to not less than [**two**] [**three**] <**Insert number**> times system size indicated with no impact to performance indicated.

E. System architecture shall perform modifications without having to remove and replace existing network equipment.

F. Number of LANs and associated communication shall be transparent to operator. All I/O points residing on any LAN shall be capable of global sharing between all system LANs.

G. System design shall eliminate dependence on any single device for system alarm reporting and control execution. Each controller shall operate independently by performing its' own control, alarm management and historical data collection.

H. Special Network Architecture Requirements:

1. Air-Handling Systems: For control applications of an air-handling system that consists of air-handling unit(s) and VAV terminal units, include a dedicated LAN of application-specific controllers serving VAV terminal units connected directly to controller that is controlling air-handling system air-handling unit(s). Basically, create a DDC system LAN that aligns with air-handling system being controlled.
2. <**Insert additional requirements**>.

2.7 DDC SYSTEM OPERATOR INTERFACES

A. Operator Means of System Access: Operator shall be able to access entire DDC system through any of multiple means, including, but not limited to, the following:

1. Desktop and portable workstation with hardwired connection through LAN port.
2. Portable operator terminal with hardwired connection through LAN port.
3. Portable operator workstation with wireless connection through LAN router.
4. Mobile device and application with secured wireless connection through LAN router or cellular data service.
5. Remote connection through web access.

B. Access to system, regardless of operator means used, shall be transparent to operator.

C. Network Ports: For hardwired connection of desktop or portable workstation. Network port shall be easily accessible, properly protected, clearly labeled, and installed at the following locations:

Seven subparagraphs below are examples only.

1. Each mechanical equipment room.
2. Each boiler room.
3. Each chiller room or outdoor chiller yard.
4. Each cooling tower location.
5. Each different roof level with roof-mounted air-handling units or rooftop units.

6. Security system command center.
7. Fire-alarm system command center.

D. Desktop Workstations:

1. Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
2. Able to communicate with any device located on any DDC system LAN.

E. Portable Workstations:

1. Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
2. Able to communicate with any device located on any DDC system LAN.
3. Connect to DDC system [**Level two**] [**or**] [**Level three**] LAN through a communications port on an application-specific controller, or a room temperature sensor connected to an application-specific controller.
4. Connect to system through a wireless router connected to Level one LAN.
5. Connect to system through a cellular data service.
6. Portable workstation shall be able to communicate with any device connected to any system LAN regardless of point of physical connection to system.
7. Monitor, program, schedule, adjust set points, and report capabilities of I/O connected anywhere in system.
8. Have dynamic graphic displays that are identical to desktop workstations.

F. POT:

1. Connect DDC controller through a communications port local to controller.
2. Able to communicate with any DDC system controller that is directly connected [**or with LAN**] [**or connected to DDC system**].

G. Mobile Device:

1. Connect to system through a wireless router connected to LAN [**and cellular data service**].
2. Able to communicate with any DDC controller connected to DDC system using [**a dedicated application**] [**and**][**secure web access**].

Retain "Telephone Communications" Paragraph below for legacy systems.

H. Telephone Communications:

1. Through use of a standard modem, operator shall be able to communicate with any device connected to any system LAN.
2. Have auto-dial and auto-answer communications to allow desktop and portable workstations and DDC controllers to communicate with remote workstations and remote DDC controllers via telephone lines.

a. Desktop and Portable Workstations:

1) Operators shall be able to perform all control functions, report functions, and database generation and modification functions as if directly connected to system LAN.
2) Have routines to automatically answer calls, and either file or display information sent remotely.
3) Communications taking place over telephone lines shall be completely transparent to operator.
4) Dial-up program shall maintain a user-definable cross-reference and associated telephone numbers so it is not required to remember or manually dial telephone numbers.

b. DDC Controllers:

1) Not have modems unless specifically indicated for a unique controller.
2) Controllers with modems shall automatically place calls to report critical alarms, or to upload trend and historical information for archiving.
3) Analyze and prioritize alarms to minimize initiation of calls.
4) Buffer noncritical alarms in memory and report them as a group of alarms, or until an operator manually requests an upload.
5) Make provisions for handling busy signals, no-answers, and incomplete data transfers.
6) Call default devices when communications cannot be established with primary devices.

I. Critical Alarm Reporting:

1. Operator-selected critical alarms shall be sent by DDC system to notify operator of critical alarms that require immediate attention.
2. DDC system shall send alarm notification to multiple recipients that are assigned for each alarm.
3. DDC system shall notify recipients by any or all means, including e-mail, text message and prerecorded phone message to mobile and landline phone numbers.

J. Simultaneous Operator Use: Capable of accommodating up to [**five**] [**10**] [**20**] <**Insert number**> simultaneous operators that are accessing DDC system through any one of operator interfaces indicated.

2.8 NETWORKS

A. Acceptable networks for connecting workstations, mobile devices, and network controllers include the following:

Retain applicable subparagraphs below to suit DDC system size and complexity. See Evaluations.

1. ATA 878.1, ARCNET.
2. CEA-709.1-C.
3. IP.
4. IEEE 8802-3, Ethernet.
5. <**Insert type**>.

B. Acceptable networks for connecting programmable application controllers include the following:

Retain applicable subparagraphs below to suit DDC system size and complexity. See Evaluations.

1. ATA 878.1, ARCNET.
2. CEA-709.1-C.
3. IP.
4. IEEE 8802-3, Ethernet.
5. <**Insert type**>.

C. Acceptable networks for connecting application-specific controllers include the following:

Retain applicable subparagraphs below to suit DDC system size and complexity. See Evaluations.

1. ATA 878.1, ARCNET.
2. CEA-709.1-C.
3. EIA-485A.
4. IP.
5. IEEE 8802-3, Ethernet.
6. <**Insert type**>.

2.9 NETWORK COMMUNICATION PROTOCOL

See Evaluations for additional information on network communication protocols.

A. Network communication protocol(s) used throughout entire DDC system shall be open to Owner and available to other companies for use in making future modifications to DDC system.

Retain "ASHRAE 135 Protocol" Paragraph below to limit entire DDC system communication protocol to ASHRAE 135.

B. ASHRAE 135 Protocol:

1. ASHRAE 135 communication protocol shall be sole and native protocol used throughout entire DDC system.
2. DDC system shall not require use of gateways except to integrate HVAC equipment and other building systems and equipment, not required to use ASHRAE 135 communication protocol.
3. If used, gateways shall connect to DDC system using ASHRAE 135 communication protocol and Project object properties and read/write services indicated by interoperability schedule.
4. Operator workstations, controllers and other network devices shall be tested and listed by BACnet Testing Laboratories.

Retain "CEA-709.1-C Protocol" Paragraph below to limit entire DDC system communication protocol to CEA-709.1-C.

C. CEA-709.1-C Protocol:

1. DDC system shall be an open implementation of LonWorks technology using CEA 709.1-C communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for communication throughout DDC system.
2. LNS shall be used for all network management including addressing and binding of network variables.

   a. Final LNS database shall be submitted with Project closeout submittals.
   b. All devices shall be online and commissioned into LNS database.

3. All devices connected to DDC system network(s) shall use CEA-709.1-C protocol and be installed so SCPT output from any node on network can be bound to any other node in the domain.

Retain "Industry Standard Protocols" Paragraph below to give choice to use one or multiple industry standard protocols.

D. Industry Standard Protocols:

1. DDC system shall use any one or a combination of the following industry standard protocols for network communication while complying with other DDC system requirements indicated:

First four subparagraphs below are examples only.

   a. ASHRAE 135.
   b. CEA-709.1-C.
   c. Modbus Application Protocol Specification V1.1b.
   d. <**Insert standard protocol**>.

2. Operator workstations [**and network controllers**]shall communicate through [**ASHRAE 135**] [**or**] [**CEA-709.1-C**] protocol.
3. Portions of DDC system networks using ASHRAE 135 communication protocol shall be an open implementation of network devices complying with ASHRAE 135. Network devices shall be tested and listed by BACnet Testing Laboratories.
4. Portions of DDC system networks using CEA-709.1-C communication protocol shall be an open implementation of LonWorks technology using CEA-709.1-C communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for DDC system.
5. Portions of DDC system networks using Modbus Application Protocol Specification V1.1b communication protocol shall be an open implementation of network devices and technology complying with Modbus Application Protocol Specification V1.1b.
6. Gateways shall be used to connect networks and network devices using different protocols.

2.10 DDC SYSTEM WIRELESS NETWORKS

A. Use [**Zigbee**] [**or**] [**an open industry standard and technology used by multiple DDC system manufacturers**] <**Insert wireless technology**> technology to create a wireless mesh network to provide wireless connectivity for network devices at multiple system levels including communications from programmable application controllers and application-specific controllers to temperature sensors and from network controllers to programmable application controllers and application-specific controllers.

B. Installer shall design wireless networks to comply with DDC system performance requirements indicated. Wireless network devices shall co-exist on same network with hardwired devices.

C. Hardwired controllers shall be capable of retrofit to wireless devices with no special software.

D. A wireless coordinator shall provide a wireless interface between programmable application controllers, application-specific controllers, and network controllers.

E. Wireless Coordinators:

1. Each wireless mesh network shall use wireless coordinator(s) for initiation and formation of network.
2. Use direct sequence spread spectrum RF technology.
3. Operate on the 2.4-GHz ISM Band.
4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
5. FCC compliant to 47 CFR 15, Subpart B, Class A.
6. Operate as a bidirectional transceiver with sensors and routers to confirm and synchronize data transmission.
7. Capable of communication with sensors and routers up to a maximum distance of 250 feet in line of sight.
8. Include visual indicators to provide diagnostic information required for operator verification of operation.

F. Wireless Routers:

1. Each wireless mesh network shall use wireless routers with any controller to provide a wireless interface to a network controller, through a wireless coordinator.
2. Use direct sequence spread spectrum RF technology.
3. Operate on the 2.4-GHz ISM Band.
4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
5. FCC compliant to 47 CFR 15, Subpart B, Class A.
6. Operate as a bidirectional transceiver with other mesh network devices to ensure network integrity.
7. Capable of communication with other mesh network devices at a maximum distance of 250 feet in line of sight.
8. Include indication for use in commissioning and troubleshooting.

G. Wireless Temperature Sensors:

1. Wireless temperature sensors shall sense and transmit room temperatures, temperature set point, room occupancy notification and low battery condition to an associated router.
2. Use direct sequence spread spectrum RF technology.
3. Operate on the 2.4-GHz ISM Band.
4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
5. FCC compliant to CFR 15, Subpart B, Class A.
6. Include set point adjustment between 55 to 85 deg F.

7. Multiple sensors shall be able to report to a router connected to a DDC controller for averaging or high and low selection.

H. One-to-One Wireless Network Receivers:

1. One-to-one wireless receivers shall receive wireless RF signals containing temperature data from multiple wireless room temperature sensors and communicate information to programmable application controllers or application-specific controllers.

a. Use direct sequence spread spectrum RF technology.
b. Operate on the 2.4-GHz ISM Band.
c. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
d. FCC compliant to 47 CFR 15, Subpart B, Class A.
e. Operate as a bidirectional transceiver with the sensors to confirm and synchronize data transmission.
f. Capable of communication up to a distance of 200 feet.
g. Include visual indication of the following:

1) Power.
2) Receiver activity.
3) Wireless RF transmission from wireless sensors.
4) No transmission, weak signal, adequate signal or excellent signal.

I. One-to-One Wireless Network Sensors:

1. One-to-one wireless sensors shall sense and report room temperatures to one-to-one receiver.

a. Use direct sequence spread spectrum RF technology.
b. Operate on the 2.4-GHz ISM Band.
c. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
d. FCC compliant to CFR 15, Subpart B, Class A.
e. Include set point adjustment between 55 to 85 deg F.

2.11 DESKTOP WORKSTATIONS

If multiple desktop workstations having unique requirements are required, copy this article and re-edit for each workstation's requirements.

A. Description: A tower or all-in-one computer designed for normal use at a single, semipermanent location.

B. <Double click here to find, evaluate, and insert list of manufacturers and products.>

C. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.

2. Energy Star compliant.

D. Personal Computer:

1. Minimum Processor Speed: <**Insert gigahertz**>.
2. RAM:

a. Capacity: [**2**] [**4**] [**8**] <**Insert value**> [**GB**].
b. Speed and Type: [**1333**] <**Insert value**> MHz, <**Insert type**>.

3. Hard Drive:

a. Media: [**Solid state**] [**Rotating disc, nominal rotational speed of 7200 rpm**] [**Hybrid solid-state and rotating disc**].
b. Number of Hard Drives: [**One**] [**Two**] <**Insert number**>.
c. Capacity: <**Insert number and measurement unit**>.
d. Minimum Average Seek Time: <**Insert number and measurement unit**>.
e. Cache Buffer Size: <**Insert number and measurement unit**>.
f. <**Insert requirements**>.

4. Second Hard Drive:

a. Media: [**Solid state**] [**Rotating disc, nominal rotational speed of 7200 rpm**] [**Hybrid solid-state and rotating disc**].
b. Capacity: <**Insert number and measurement unit**>.
c. Minimum Average Seek Time: <**Insert number and measurement unit**>.
d. Cache Buffer Size: <**Insert number and measurement unit**>.
e. <**Insert requirements**>.

5. Optical Drive:

a. Type: <**Insert type**>.
b. Minimum Average Access Time: <**Insert number**> ms.
c. Data Transfer Speed: <**Insert number**> [**MB**] [**TB**]/s.
d. Reading Formats: Data, audio, recordable, <**Insert other**> and rewritable.

6. Optical Read and Write Drive:

a. Include with at least 2 MB of data buffer.
b. Type: <**Insert type**>.
c. Minimum Data Buffer Capacity: <**Insert number and measurement unit**>.
d. Minimum Average Access Time: <**Insert number**> ms.
e. Nominal Data Transfer Rates:

1) Reading: <**Insert number**> [**MB**] [**TB**]/s.
2) Writing: <**Insert number**> [**MB**] [**TB**]/s.

f. Average access time of 150 ms or less.
g. MTBF of at least 100,000 power-on hours.

7. At least four expansion slots of [**32**] [**64**] <**Insert number**> bit.

8. Video Card:

    a. Resolution: [**1920 by 1200**] <**Insert values**> pixels.
    b. RAM: <**Insert number**> [**MB**] [**GB**] [**TB**].
    c. Controller Speed: <**Insert number**> [**MHz**] [**GHz**].
    d. On-Board Memory Speed: <**Insert number**> [**MHz**] [**GHz**].
    e. On-Board Memory Data Width: <**Insert number**> bit.

9. Sound Card:

    a. At least 128 voice wavetable synthesis.
    b. Capable of delivering three-dimensional sound effects.
    c. High-resolution 16-bit stereo digital audio recording and playback with user-selectable sample rates up to 48,000 Hz.

10. Network Interface Card: Include card with connection, as applicable.

    a. 10-100-1000 base TX Ethernet with RJ45 connector port.
    b. 100 base FX Ethernet with SC or ST port.

E. Wireless Ethernet, 802.11 a/b/g/n.

Retain "Optical Modem" Subparagraph below for direct connection to optical fiber cable.

1. Optical Modem: Full duplex link for connection to optical fiber cable provided.
2. I/O Ports:

    a. Two USB 3.0 ports on front panel, six on back panel, and three internal on motherboard.
    b. One serial port.
    c. One parallel port.
    d. Two PS/2 ports.
    e. One RJ-45.
    f. One stereo line-in and headphone/line-out on back panel.
    g. One microphone and headphone connector on front panel.
    h. One IEEE 1394 on front and back panel with PCI-e card.
    i. One ESATA port on back panel.

3. Battery: Life of at least three years to maintain system clock/calendar and ROM, as a minimum.

F. Keyboard:

1. 101 enhanced keyboard.
2. Full upper- and lowercase ASCII keyset, numeric keypad, dedicated cursor control keypad, and 12 programmable function keys.
3. Wireless operation within up to 72 inches in front of workstation.

G. Pointing Device:

1. Either a two- or three-button mouse.

2. Wireless operation within up to 72 inches in front of workstation.

H. Flat Panel Display Monitor:

Copy and re-edit "Display" Subparagraph below if requirements are different for multiple displays.

1. Display:

a. Color display with <**Insert inches**> diagonal viewable area.
b. [**Digital**] [**or**] [**analog**] input signal.
c. Aspect Ratio: [**16 to 9**] <**Insert value**>.
d. Antiglare display.
e. Response Time: <**Insert number**> ms.
f. Dynamic Contrast Ratio: [**50000 to 1**] <**Insert ratio**>.
g. Brightness: [**250 cd/sq. m**] <**Insert value**>.
h. Tilt adjustable base.
i. Energy Star compliant.
j. Resolution: [**1920 by 1080**] <**Insert value**> pixels at 60 Hz with pixel size of [**0.277**] <**Insert number**> mm or smaller.
k. Number of Displays: [**One**] [**Two**] <**Insert number**>.

I. Speakers:

1. Two, with individual controls for volume, bass and treble.
2. Signal to Noise Ratio: At least 65 dB.
3. Power: At least 4 W per speaker/channel.
4. Magnetic shielding to prevent distortion on the video monitor.

J. I/O Cabling: Include applicable cabling to connect I/O devices.

2.12 PORTABLE WORKSTATIONS

If multiple portable workstations having unique requirements are required, copy this article and re-edit to specify requirements for each workstation.

A. Description: A self-contained computer designed to allow for normal use in different locations and conditions.

B. <Double click here to find, evaluate, and insert list of manufacturers and products.>

C. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
2. Energy Star compliant.
3. Hardware and software shall support local down-loading to DDC controllers.
4. Data transfer rate to DDC controller shall be at network speed.

D. Processor:

1. Minimum Processor Speed: <**Insert gigahertz**>.

2. RAM:

   a. Capacity: <**Insert value**> [**GB**] [**TB**].
   b. Speed and Type: <**Insert value**> MHz, <**Insert type**>.

Copy and re-edit "Hard Drive" Subparagraph below if requirements are different for multiple hard drives.

3. Hard Drive:

   a. Number of Hard Drives: [**One**] [**Two**] <**Insert number**>.
   b. Capacity: <**Insert number and measurement unit**>.
   c. Minimum Average Seek Time: <**Insert number and measurement unit**>.
   d. Cache Buffer Size: <**Insert number and measurement unit**>.
   e. <**Insert requirements**>.

4. Video Card: <**Insert number and measurement unit**> of RAM.

E. Input and Output Ports:

1. Serial port.
2. Shared port for external keyboard or mouse.
3. Four USB 3.0 ports.
4. Ethernet port.
5. HDMI port.
6. IEEE 1394 port.

F. Battery:

1. Capable of supporting operation of portable workstation for a minimum of [**8**] <**Insert number**> hours.
2. Battery life of at least three years.
3. Battery charge time of less than three hours.
4. Spare Battery(ies). [**One**] [**Two**].

G. Keyboard:

1. 85-key [**backlit**]keyboard.
2. Full upper- and lowercase ASCII keyset.

H. Integral Pointing Device: Touchpad with two buttons. Gesture enabled.

I. Display:

1. <**Insert inches**> diagonal or larger high-definition WLED color display.
2. Antiglare screen.
3. [**1920 by 1080**] <**Insert value**> pixel resolution.
4. Brightness: 300 nits.

J. Network Interfaces:

1. Network Interface Card: Include card with connection, as application.

a. 10-100-1000 base TX Ethernet with RJ45 connector port.
b. 100 base FX Ethernet with SC or ST port.

2. Wireless:

a. Internal with integrated antenna, capable of supporting 802.11 a/b/g/n.

K. Digital Video Disc Rewrite Recorder (DVD+/-RW):

1. Compatible with DVD disks and data, audio, recordable and rewritable compact disks.
2. Nominal Data Transfer Rates:

a. Reading: <**Insert number**> [**MB**] [**TB**]/s.
b. Writing: <**Insert number**> [**MB**] [**TB**]/s.

3. 160-ms access time.

L. Accessories:

1. Nylon carrying case.
2. Docking station.
3. Mobile broadband card.
4. Wireless optical mouse.
5. <**Insert value**> [**GB**] [**TB**] portable hard drive.
6. Light-sensitive web cam and noise-cancelling digital array microphone.
7. Category 6a patch cable. Minimum cable length shall be <**Insert length**>.
8. HDMI cable. Minimum cable length shall be <**Insert length**>.

2.13 PORTABLE OPERATOR TERMINAL

A. Description: Handheld device with integral keypad or touch screen operator interface.

B. Display: Multiple lines of text display for use in operator interaction with DDC system.

C. Cable: Flexible [**coiling**]cable, at least 36 inches long, with a plug-in jack for connection to DDC controllers, network ports or instruments with an integral LAN port. As an alternative to hardwired connection, POT shall be accessible to DDC controllers through a wireless network connection.

D. POT shall be powered through network connection.

E. Connection of POT to DDC system shall not interrupt or interfere with normal network operation in any way, prevent alarms from being transmitted, or preclude central initiated commands and system modification.

F. POT shall give operator the ability to do the following:

Remaining subparagraphs below are examples only.

1. Display and monitor BI point status.
2. Change BO point set point (on or off, open or closed).

3. Display and monitor analog point values.
4. Change analog control set points.
5. Command a setting of AO point.
6. Display and monitor I/O point in alarm.
7. Add a new or delete an existing I/O point.
8. Enable and disable I/O points, initiators, and programs.
9. Display and change time and date.
10. Display and change time schedules.
11. Display and change run-time counters and run-time limits.
12. Display and change time and event initiation.
13. Display and change control application and DDC parameters.
14. Display and change programmable offset values.
15. Access DDC controller initialization routines and diagnostics.
16. <**Insert requirements**>.

2.14 SERVERS

Retain this article for DDC systems with large data storage requirements.

A. Description: x86 based permanently installed computer used for client-server computing.

B. <Double click here to find, evaluate, and insert list of manufacturers and products.>

C. Mounting: [**Rack**] [**Blade**] [**Tower**] [**Tower able to be rack-mounted**].

D. Power: [**Single**] [**Dual**] power supply, minimum 300 W.

E. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
2. Energy Star compliant.
3. Minimum Processor Speed: <**Insert gigahertz**>.
4. RAM:

   a. Capacity: <**Insert value**> [**GB**] [**TB**].
   b. Speed and Type: <**Insert value**> MGz, <**Insert type**>.
   c. Expandable Capacity: <**Insert value**> [**GB**] [**TB**].

See Evaluations for discussion of redundant array of independent disks levels.

5. Redundant Array of Independent Disks: [**Zero**] [**One**] [**Two**] [**Three**] [**Four**] [**Five**] <**Insert number**> configuration.
6. Drive Bays: Eight at 2.5 inches or eight at 3.5 inches.
7. Hard-Drive Storage: [**Two**] [**Three**] [**Four**] drives each with <**Insert value**> [**GB**] [**TB**] storage and nominal rotational speed of 7200 rpm.
8. Network Interface: [**Dual port Gigabit Ethernet**] [**Optical fiber**].
9. DVD +RW Drive.
10. Color, flat-screen display with <**Insert inches**> diagonal viewable area.
11. Keyboard and mouse.

12. Next-day on-site warranty for [**two**] [**three**] <**Insert number**>-year period following Substantial Completion.

F. Servers shall include the following:

1. Full-feature backup server (server and backup minimum requirement).
2. Software licenses.
3. Cable installation between server(s) and network.

G. Web Server:

1. If required to be separate, include Web server hardware and software to match, except backup server is not required.
2. Firewalls between server Web and networks.
3. Password protection for access to server from Web server.
4. Cable installation between the server(s) and building Ethernet network.

H. Power each server through a [**dedicated**]UPS unit.

2.15 PRINTERS

A. Black and White Laser Printer:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. [**1200 by 1200**] <**Insert value**> dots per inch resolution.
3. First sheet printed within 10 seconds.
4. <**Insert number**> page per minute rated print speed at best quality mode.
5. Print buffer with at least <**Insert value**> MB of RAM, expandable to at least 288 MBs.
6. Complies with Energy Star requirements.
7. Capable of handling letter- and legal-size paper and overhead transparencies.
8. Two paper trays; one tray with <**Insert number**> sheet capacity, and one tray with <**Insert number**> sheet capacity.
9. At least <**Insert number**> page toner/cartridge capacity.

B. Color Laser Printer:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. [**1200 by 1200**] <**Insert value**> dots per inch resolution black and white, [**1200 by 1200**] <**Insert value**> dots per inch resolution black and white and color.
3. First sheet printed within 10 seconds.
4. <**Insert number**> page per minute rated print speed at best quality mode.
5. Print buffer with at least [**512**] <**Insert value**> MB of RAM, expandable to at least [**one**] <**Insert value**> GB.
6. Complies with Energy Star requirements.
7. Capable of handling letter- and legal-size paper and overhead transparencies.
8. Two paper trays; one tray with <**Insert number**> sheet capacity, and one tray with 500 <**Insert number**> sheet capacity.
9. Two-sided printing.
10. At least <**Insert number**> page toner/cartridge capacity.

C. Color Inkjet Printer:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Inkjet technology with true four-color printing (black, cyan, magenta, and yellow).
3. Print quality of [**1200 by 600**] <**Insert value**> dots per inch with black on inkjet paper and [**4800 by 1200**] <**Insert value**> dots per inch color printing on premium photo paper.
4. Rated speed of <**Insert number**> pages per minute printing black and white in normal mode and <**Insert number**> pages per minute printing color in normal mode.
5. Two paper trays; one tray with <**Insert number**> sheet capacity, and one tray with <**Insert number**> sheet capacity.
6. Capable of handling letter- and legal-size paper and overhead transparencies.
7. <**Insert number**> MB of RAM.
8. Duplex printing (printing on both sides of paper).

D. Dot Matrix Printer:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Letter-quality, wide-carriage, 24-pin dot matrix printer.
3. <**Insert number**> kb print buffer.
4. Minimum Print Speed:

   a. 330 characters per second (draft).
   b. 110 characters per second (letter quality).

5. Seven print fonts.
6. Continuous - forms feed with manual single sheet feed.
7. Capable of handling 16-inch-wide continuous-feed paper.

2.16 SYSTEM SOFTWARE

A. System Software Minimum Requirements:

1. Real-time multitasking and multiuser [**32-**] [**or**] [**64-**]bit operating system that allows concurrent multiple operator workstations operating and concurrent execution of multiple real-time programs and custom program development.
2. Operating system shall be capable of operating DOS and Microsoft Windows applications.
3. Database management software shall manage all data on an integrated and non-redundant basis. Additions and deletions to database shall be without detriment to existing data. Include cross linkages so no data required by a program can be deleted by an operator until that data have been deleted from respective programs.
4. Network communications software shall manage and control multiple network communications to provide exchange of global information and execution of global programs.
5. Operator interface software shall include day-to-day operator transaction processing, alarm and report handling, operator privilege level and data segregation control, custom programming, and online data modification capability.
6. Scheduling software shall schedule centrally based time and event, temporary, and exception day programs.

B. Operator Interface Software:

1. Minimize operator training through use of English language prorating and English language point identification.
2. Minimize use of a typewriter-style keyboard through use of a pointing device similar to a mouse.
3. Operator sign-off shall be a manual operation or, if no keyboard or mouse activity takes place, an automatic sign-off.
4. Automatic sign-off period shall be programmable from one to 60 minutes in one-minute increments on a per operator basis.
5. Operator sign-on and sign-off activity shall be recorded and sent to printer.
6. Security Access:

    a. Operator access to DDC system shall be under password control.
    b. An alphanumeric password shall be field assignable to each operator.
    c. Operators shall be able to access DDC system by entry of proper password.
    d. Operator password shall be same regardless of which computer or other interface means is used.
    e. Additions or changes made to passwords shall be updated automatically.
    f. Each operator shall be assigned an access level to restrict access to data and functions the operator is cable of performing.
    g. Software shall have at least five access levels.
    h. Each menu item shall be assigned an access level so that a one-for-one correspondence between operator assigned access level(s) and menu item access level(s) is required to gain access to menu item.
    i. Display menu items to operator with those capable of access highlighted. Menu and operator access level assignments shall be online programmable and under password control.

7. Data Segregation:

    a. Include data segregation for control of specific data routed to a workstation, to an operator or to a specific output device, such as a printer.
    b. Include at least [**32**] <**Insert number**> segregation groups.
    c. Segregation groups shall be selectable such as "fire points," "fire points on second floor," "space temperature points," "HVAC points," and so on.
    d. Points shall be assignable to multiple segregation groups. Display and output of data to printer or monitor shall occur where there is a match of operator or peripheral segregation group assignment and point segregations.
    e. Alarms shall be displayed and printed at each peripheral to which segregation allows, but only those operators assigned to peripheral and having proper authorization level will be allowed to acknowledge alarms.
    f. Operators and peripherals shall be assignable to multiple segregation groups and all assignments are to be online programmable and under password control.

8. Operators shall be able to perform commands including, but not limited to, the following:

    a. Start or stop selected equipment.
    b. Adjust set points.
    c. Add, modify, and delete time programming.
    d. Enable and disable process execution.

e. Lock and unlock alarm reporting for each point.
f. Enable and disable totalization for each point.
g. Enable and disable trending for each point.
h. Override control loop set points.
i. Enter temporary override schedules.
j. Define holiday schedules.
k. Change time and date.
l. Enter and modify analog alarm limits.
m. Enter and modify analog warning limits.
n. View limits.
o. Enable and disable demand limiting.
p. Enable and disable duty cycle.
q. Display logic programming for each control sequence.
r. <**Insert requirements**>.

9. Reporting:

a. Generated automatically and manually.
b. Sent to displays, printers and disk files.
c. Types of Reporting:

1) General listing of points.
2) List points currently in alarm.
3) List of off-line points.
4) List points currently in override status.
5) List of disabled points.
6) List points currently locked out.
7) List of items defined in a "Follow-Up" file.
8) List weekly schedules.
9) List holiday programming.
10) List of limits and deadbands.

10. Summaries: For specific points, for a logical point group, for an operator selected group(s), or for entire system without restriction due to hardware configuration.

C. Graphic Interface Software:

1. Include a full interactive graphical selection means of accessing and displaying system data to operator. Include at least five levels with the penetration path operator assignable (for example, site, building, floor, air-handling unit, and supply temperature loop). Native language descriptors assigned to menu items are to be operator defined and modifiable under password control.
2. Include a hierarchical-linked dynamic graphic operator interface for accessing and displaying system data and commanding and modifying equipment operation. Interface shall use a pointing device with pull-down or penetrating menus, color and animation to facilitate operator understanding of system.
3. Include at least 10 levels of graphic penetration with the hierarchy operator assignable.
4. Descriptors for graphics, points, alarms and such shall be modified through operator's workstation under password control.
5. Graphic displays shall be online user definable and modifiable using the hardware and software provided.

6. Data to be displayed within a graphic shall be assignable regardless of physical hardware address, communication or point type.
7. Graphics are to be online programmable and under password control.
8. Points may be assignable to multiple graphics where necessary to facilitate operator understanding of system operation.
9. Graphics shall also contain software points.
10. Penetration within a graphic hierarchy shall display each graphic name as graphics are selected to facilitate operator understanding.
11. Back-trace feature shall permit operator to move upward in the hierarchy using a pointing device. Back trace shall show all previous penetration levels. Include operator with option of showing each graphic full screen size with back trace as horizontal header or by showing a "stack" of graphics, each with a back trace.
12. Display operator accessed data on the monitor.
13. Operator shall select further penetration using pointing device to click on a site, building, floor, area, equipment, and so on. Defined and linked graphic below that selection shall then be displayed.
14. Include operator with means to directly access graphics without going through penetration path.
15. Dynamic data shall be assignable to graphics.
16. Display points (physical and software) with dynamic data provided by DDC system with appropriate text descriptors, status or value, and engineering unit.
17. Use color, rotation, or other highly visible means, to denote status and alarm states. Color shall be variable for each class of points, as chosen by operator.
18. Points shall be dynamic with operator adjustable update rates on a per point basis from [**one**] <**Insert value**> second to over a [**minute**] <**Insert value**>.
19. For operators with appropriate privilege, points shall be commanded directly from display using pointing device.

    a. For an analog command point such as set point, current conditions and limits shall be displayed and operator can position new set point using pointing device.
    b. For a digital command point such as valve position, valve shall show its current state such as open or closed and operator could select alternative position using pointing device.
    c. Keyboard equivalent shall be available for those operators with that preference.

20. Operator shall be able to split or resize viewing screen into quadrants to show one graphic on one quadrant of screen and other graphics or spreadsheet, bar chart, word processing, curve plot and other information on other quadrants on screen. This feature shall allow real-time monitoring of one part of system while displaying other parts of system or data to better facilitate overall system operation.
21. Help Features:

    a. On-line context-sensitive help utility to facilitate operator training and understanding.
    b. Bridge to further explanation of selected keywords. Document shall contain text and graphics to clarify system operation.

        1) If help feature does not have ability to bridge on keywords for more information, a complete set of user manuals shall be provided in an indexed word-processing program, which shall run concurrently with operating system software.

c. Available for Every Menu Item:

1) Index items for each system menu item.

22. Graphic generation software shall allow operator to add, modify, or delete system graphic displays.

a. Include libraries of symbols depicting HVAC symbols such as fans, coils, filters, dampers, valves pumps, and electrical symbols[**similar to those indicated**].
b. Graphic development package shall use a pointing device in conjunction with a drawing program to allow operator to perform the following:

1) Define background screens.
2) Define connecting lines and curves.
3) Locate, orient and size descriptive text.
4) Define and display colors for all elements.
5) Establish correlation between symbols or text and associated system points or other displays.

D. Project-Specific Graphics: Graphics documentation including, but not limited to, the following:

Subparagraphs below are examples only.

1. Site plan showing each building, and additional site elements, which are being controlled or monitored by DDC system.
2. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:

a. Room layouts with room identification and name.
b. Locations and identification of all monitored and controlled HVAC equipment and other equipment being monitored and controlled by DDC system.
c. Location and identification of each hardware point being controlled or monitored by DDC system.
d. <**Insert requirements**>.

3. Control schematic for each of following, including a graphic system schematic representation[**, similar to that indicated on Drawings,**] with point identification, set point and dynamic value indication[**, sequence of operation**] [**and**] [**control logic diagram**].
4. Graphic display for each piece of equipment connected to DDC system through a data communications link. Include dynamic indication of all points associated with equipment.
5. DDC system network riser diagram that shows schematic layout for entire system including all networks and all controllers, [**gateways**] [**operator workstations**] [**and**] [**other network devices**].

E. Customizing Software:

1. Software to modify and tailor DDC system to specific and unique requirements of equipment installed, to programs implemented and to staffing and operational practices planned.

2. Online modification of DDC system configuration, program parameters, and database using menu selection and keyboard entry of data into preformatted display templates.
3. As a minimum, include the following modification capability:

    a. Operator assignment shall include designation of operator passwords, access levels, point segregation and auto sign-off.
    b. Peripheral assignment capability shall include assignment of segregation groups and operators to consoles and printers, designation of backup workstations and printers, designation of workstation header points and enabling and disabling of print-out of operator changes.
    c. System configuration and diagnostic capability shall include communications and peripheral port assignments, DDC controller assignments to network, DDC controller enable and disable, assignment of command trace to points and application programs and initiation of diagnostics.
    d. System text addition and change capability shall include English or native language descriptors for points, segregation groups and access levels and action messages for alarms, run time and trouble condition.
    e. Time and schedule change capability shall include time and date set, time and occupancy schedules, exception and holiday schedules and daylight savings time schedules.
    f. Point related change capability shall include the following:

        1) System and point enable and disable.
        2) Run-time enable and disable.
        3) Assignment of points to segregation groups, calibration tables, lockout, and run time and to a fixed I/O value.
        4) Assignment of alarm and warning limits.

    g. Application program change capability shall include the following:

        1) Enable and disable of software programs.
        2) Programming changes.
        3) Assignment of comfort limits, global points, time and event initiators, time and event schedules and enable and disable time and event programs.

4. Software shall allow operator to add points, or groups of points, to DDC system and to link them to energy optimization and management programs. Additions and modifications shall be online programmable using operator workstation, downloaded to other network devices and entered into their databases. After verification of point additions and associated program operation, database shall be uploaded and recorded on hard drive and disk for archived record.
5. Include high-level language programming software capability for implementation of custom DDC programs. Software shall include a compiler, linker, and up- and down-load capability.
6. Include a library of DDC algorithms, intrinsic control operators, arithmetic, logic and relational operators for implementation of control sequences. Also include, as a minimum, the following:

    a. Proportional control (P).
    b. Proportional plus integral (PI).
    c. Proportional plus integral plus derivative (PID).

d. Adaptive and intelligent self-learning control.

1) Algorithm shall monitor loop response to output corrections and adjust loop response characteristics according to time constant changes imposed.
2) Algorithm shall operate in a continuous self-learning manner and shall retain in memory a stored record of system dynamics so that on system shut down and restart, learning process starts from where it left off.

7. Fully implemented intrinsic control operators including sequence, reversing, ratio, time delay, time of day, highest select AO, lowest select AO, analog controlled digital output, analog control AO, and digitally controlled AO.
8. Logic operators such as "And," "Or," "Not," and others that are part of a standard set available with a high-level language.
9. Arithmetic operators such as "Add," "Subtract," "Multiply," "Divide," and others that are part of a standard set available with a high-level language.
10. Relational operators such as "Equal To," "Not Equal To," "Less Than," "Greater Than," and others that are part of a standard set available with a high-level language.

F. Alarm Handling Software:

1. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers[**, gateways**] [**and other network devices**].
2. Include first in, first out handling of alarms according to alarm priority ranking, with most critical alarms first, and with buffer storage in case of simultaneous and multiple alarms.
3. Alarm handling shall be active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system.
4. Alarms display shall include the following:

a. Indication of alarm condition such as "Abnormal Off," "Hi Alarm," and "Low Alarm."
b. "Analog Value" or "Status" group and point identification with native language point descriptor such as "Space Temperature, Building 110, 2nd Floor, Room 212."
c. Discrete per point alarm action message, such as "Call Maintenance Dept. Ext-5561."
d. Include extended message capability to allow assignment and printing of extended action messages. Capability shall be operator programmable and assignable on a per point basis.

5. Alarms shall be directed to appropriate operator workstations, printers, and individual operators by privilege level and segregation assignments.
6. Send e-mail alarm messages to designated operators.
7. Send e-mail, page, text and voice messages to designated operators for critical alarms.
8. Alarms shall be categorized and processed by class.

a. Class 1:

1) Associated with fire, security and other extremely critical equipment monitoring functions; have alarm, trouble, return to normal, and acknowledge conditions printed and displayed.

2) Unacknowledged alarms to be placed in unacknowledged alarm buffer.
3) All conditions shall cause an audible sound and shall require individual acknowledgment to silence audible sound.

b. Class 2:

1) Critical, but not life-safety related, and processed same as Class 1 alarms, except do not require individual acknowledgment.
2) Acknowledgement may be through a multiple alarm acknowledgment.

c. Class 3:

1) General alarms; printed, displayed and placed in unacknowledged alarm buffer queues.
2) Each new alarm received shall cause an audible sound. Audible sound shall be silenced by "acknowledging" alarm or by pressing a "silence" key.
3) Acknowledgement of queued alarms shall be either on an individual basis or through a multiple alarm acknowledgement.
4) Alarms returning to normal condition shall be printed and not cause an audible sound or require acknowledgment.

d. Class 4:

1) Routine maintenance or other types of warning alarms.
2) Alarms to be printed only, with no display, no audible sound and no acknowledgment required.

9. Include an unacknowledged alarm indicator on display to alert operator that there are unacknowledged alarms in system. Operator shall be able to acknowledge alarms on an individual basis or through a multiple alarm acknowledge key, depending on alarm class.
10. To ensure that no alarm records are lost, it shall be possible to assign a backup printer to accept alarms in case of failure of primary printer.

G. Reports and Logs:

1. Include reporting software package that allows operator to select, modify, or create reports using DDC system I/O point data available.
2. Each report shall be definable as to data content, format, interval and date.
3. Report data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on [**workstation**] [**server**] for historical reporting.
4. Operator shall be able to obtain real-time logs of all I/O points by type or status, such as alarm, point lockout, or normal.
5. Reports and logs shall be stored on [**workstation**] [**and**] [**server**] hard drives in a format that is readily accessible by other standard software applications, including spreadsheets and word processing.
6. Reports and logs shall be readily printed and set to be printed either on operator command or at a specific time each day.

H. Standard Reports: Standard DDC system reports shall be provided and operator shall be able to customize reports later.

1. All I/O: With current status and values.
2. Alarm: All current alarms, except those in alarm lockout.
3. Disabled I/O: All I/O points that are disabled.
4. Alarm Lockout I/O: All I/O points in alarm lockout, whether manual or automatic.
5. Alarm Lockout I/O in Alarm: All I/O in alarm lockout that are currently in alarm.
6. Logs:

    a. Alarm history.
    b. System messages.
    c. System events.
    d. Trends.

I. Custom Reports: Operator shall be able to easily define any system data into a daily, weekly, monthly, or annual report. Reports shall be time and date stamped and shall contain a report title.

Retain "Tenant Override Reports" Paragraph below if required to report individual tenant use of above building standard HVAC operation.

J. Tenant Override Reports: Prepare Project-specific reports.

1. Weekly report showing daily total time in hours that each tenant has requested after-hours HVAC.
2. Monthly report showing daily total time in hours that each tenant has requested after-hours HVAC.
3. Annual summary report that shows after-hours HVAC usage on a monthly basis.

Retain "HVAC Equipment Reports" Paragraph below to require Project-specific HVAC equipment reports to be prepared by a DDC system installer.

K. HVAC Equipment Reports: Prepare Project-specific reports.

1. Chiller Report: Daily report showing operating conditions of each chiller according to ASHRAE 147, including, but not limited to, the following:

Revise subparagraphs below to suit Project. Include DDC system with instruments required to provide information indicated.

    a. Chilled-water entering temperature.
    b. Chilled-water leaving temperature.
    c. Chilled-water flow rate.
    d. Chilled-water inlet and outlet pressures.
    e. Evaporator refrigerant pressure and temperature.
    f. Condenser refrigerant pressure and liquid temperature.
    g. Condenser-water entering temperature.
    h. Condenser-water leaving temperature.
    i. Condenser-water flow rate.
    j. Refrigerant levels.
    k. Oil pressure and temperature.
    l. Oil level.
    m. Compressor refrigerant discharge temperature.

n. Compressor refrigerant suction temperature.
o. Addition of refrigerant.
p. Addition of oil.
q. Vibration levels or observation that vibration is not excessive.
r. Motor amperes per phase.
s. Motor volts per phase.
t. Refrigerant monitor level (PPM).
u. Purge exhaust time or discharge count.
v. Ambient temperature (dry bulb and wet bulb).
w. Date and time logged.

2. <**Insert requirements for each type of HVAC equipment requiring a report**>.

Retain "Utility Reports" Paragraph below to require Project-specific utility reports to be prepared by a DDC system installer.

L. Utility Reports: Prepare Project-specific reports.

Revise subparagraphs below to suit Project. Include DDC system with instruments required to provide reports indicated.

1. Electric Report:

a. Include weekly report showing daily electrical consumption and peak electrical demand with time and date stamp for each meter.
b. Include monthly report showing the daily electrical consumption and peak electrical demand with time and date stamp for each meter.
c. Include annual report showing the monthly electrical consumption and peak electrical demand with time and date stamp for each meter.
d. For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as lighting, receptacles and HVAC equipment showing daily electrical consumption and peak electrical demand.
e. For each weekly, monthly and annual report, include sum total of all submeters in building showing electrical consumption and peak electrical demand.

2. Natural Gas Report:

a. Include weekly report showing daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.
b. Include monthly report showing the daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.
c. Include annual report showing the monthly natural gas consumption and peak natural gas demand with time and date stamp for each meter.
d. For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as boilers and service water heaters showing daily natural gas consumption and peak natural gas demand.
e. For each weekly, monthly and annual report, include sum total of all submeters in building showing natural gas consumption and peak natural gas demand.

3. Service Water Report:

a. Include weekly report showing daily service water consumption and peak service water demand with time and date stamp for each meter.
b. Include monthly report showing the daily service water consumption and peak service water demand with time and date stamp for each meter.
c. Include annual report showing the monthly service water consumption and peak service water demand with time and date stamp for each meter.
d. For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as cooling tower makeup and irrigation showing daily service water consumption and peak service water demand.
e. For each weekly, monthly and annual report, include sum total of all submeters in building showing service water consumption and peak service water demand.

4. <**Insert requirements for each utility requiring a report**>.

Retain "Energy Reports" Paragraph below for projects with emphasis on energy performance.

M. Energy Reports: Prepare Project-specific daily, weekly, monthly [**and annual**] [**, annual and since-installed**] energy reports.

1. Prepare report for each purchased energy utility, indicating the following:

a. Time period being reported with beginning and end date, and time indicated.
b. Consumption in units of measure commonly used to report specific utility consumption over time.
c. Gross area served by utility.
d. Consumption per unit area served using utility-specific unit of measure.
e. Cost per utility unit.
f. Utility cost per unit area.
g. Convert all utilities to a common energy consumption unit of measure and report for each utility.
h. Consumption per unit area using common unit of measure.

Retain first subparagraph below to report renewable energy.

2. Prepare report for each renewable energy source, indicating the following:

a. Time period being reported with beginning and end date, and time indicated.
b. Harvested energy in units of measure commonly used to report specific harvested energy consumption over time.
c. Gross area served by renewable energy source.
d. Harvested energy per unit area served using specific unit of measure.
e. Cost per purchased utility unit displaced by renewable energy.
f. Cost savings attributed to harvested energy source.
g. Cost savings per unit area attributed to harvested energy.
h. Convert all renewable energy sources to a common energy consumption unit of measure and report for each.
i. Harvested energy per unit area using common unit of measure.

Retain first subparagraph below to report energy by submetered areas.

3. Prepare purchased energy utility report for each submetered area that indicates the following:

    a. Time period being reported with beginning and end date, and time indicated.
    b. Gross area served.
    c. Energy consumption by energy utility type.
    d. Energy consumption per unit area by energy utility type.
    e. Total energy consumption of all utilities in common units of measure.
    f. Total energy consumption of all utilities in common units of measure per unit area.
    g. Unit energy cost by energy utility type.
    h. Energy cost by energy utility type.
    i. Energy cost per unit area by energy utility type.
    j. Total cost of all energy utilities.
    k. Total cost of all energy utilities per unit area.

4. Prepare Project total purchased energy utility report that combines all purchased energy utilities and all areas served. Project total energy report shall indicate the following:

    a. Time period being reported with beginning and end date, and time indicated.
    b. Gross area served.
    c. Energy consumption by energy utility type.
    d. Energy consumption per unit area by energy utility type.
    e. Total energy consumption of all utilities in common units of measure.
    f. Total energy consumption of all utilities in common units of measure per unit area.
    g. Unit energy cost by energy utility type.
    h. Energy cost by energy utility type.
    i. Energy cost per unit area by energy utility type.
    j. Total cost of all energy utilities.
    k. Total cost of all energy utilities per unit area.

Retain "HVAC System Efficiency Reports" Paragraph below for projects with emphasis on energy performance.

N. HVAC System Efficiency Reports: Prepare Project-specific [**daily**] [**weekly**] [**monthly**] [**and annual**] [**, annual and since-installed**] HVAC system efficiency reports.

1. Prepare report for [**each**]chilled-water system, indicating the following:

    a. Time period being reported with beginning and end date, and time indicated.
    b. Cooling energy supplied during time period.
    c. Power energy consumed during time period by cooling equipment used to produce cooling energy supplied.[**List power consumed for each individual piece of equipment in system and summed total of all equipment in system.**]
    d. Energy efficiency coefficient of performance determined by dividing power energy consumed into cooling energy supplied.
    e. Energy efficiency determined by dividing cooling energy supplied into power energy consumed.
    f. Units of measure used in report shall be consistent with units indicated for system.

2. Prepare report for [**each**]hot-water system, indicating the following:

a. Time period being reported with beginning and end date, and time indicated.
b. Cooling energy supplied during time period.
c. Fuel consumed during time period by boilers used to produce heating energy supplied.[**List fuel consumed for each individual piece of equipment in system and summed total of all equipment in system.**]
d. Energy efficiency determined by dividing heating energy supplied into fuel energy consumed.
e. Units of measure used in report shall be consistent with units indicated for system.

3. Prepare report for [**each**]steam system, indicating the following:

a. Time period being reported with beginning and end date, and time indicated.
b. Cooling energy supplied during time period.
c. Fuel consumed during time period by boilers used to produce heating energy supplied.[**List fuel consumed for each individual piece of equipment in system and summed total of all equipment in system.**]
d. Energy efficiency determined by dividing heating energy supplied into fuel energy consumed.
e. Units of measure used in report shall be consistent with units indicated for system.

4. <**Insert requirements for each HVAC system requiring a report**>.

Retain "PUE Reports" Paragraph below for data center projects with emphasis on energy performance.

O. PUE Reports: Prepare Project-specific [**daily**] [**weekly**] [**monthly**] [**and annual**] [**, annual and since-installed**] PUE reports.

1. Prepare separate report for each [**tenant**] <**Insert category**>.
2. Prepare Project PUE report that combines PUE and all tenants served.
3. Calculate PUE following guidelines in [**The Green Grid, White Paper No. 22**] <**Insert requirements**>.

Retain "Weather Reports" Paragraph below to require Project-specific weather reports to be prepared by a DDC system installer.

P. Weather Reports:

Revise subparagraphs below to suit Project. Include DDC system with instruments required to provide reports indicated.

1. Include daily report showing the following:

a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
c. Daily minimum, maximum, and average outdoor dew point temperature.
d. Number of heating degree-days for each day calculated from a base temperature of [**55 deg F**] <**Insert temperature**>.
e. Number of cooling degree-days for each day calculated from a base temperature of [**65 deg F**] <**Insert temperature**>.
f. Daily minimum, maximum, and average outdoor carbon dioxide level.
g. Daily minimum, maximum, and average relative humidity.

h. Daily minimum, maximum, and average barometric pressure.
i. Daily minimum, maximum, and average wind speed and direction.

2. Include weekly report showing the following:

a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
c. Daily minimum, maximum, and average outdoor dew point temperature.
d. Number of heating degree-days for each day calculated from a base temperature of [**55 deg F**] <**Insert temperature**>.
e. Number of cooling degree-days for each day calculated from a base temperature of [**65 deg F**] <**Insert temperature**>.
f. Weekly minimum, maximum, and average outdoor carbon dioxide level.
g. Daily minimum, maximum, and average relative humidity.
h. Daily minimum, maximum, and average barometric pressure.
i. Daily minimum, maximum, and average wind speed and direction.

3. Include monthly report showing the following:

a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
c. Daily minimum, maximum, and average outdoor dew point temperature.
d. Number of heating degree-days for each day calculated from a base temperature of [**55 deg F**] <**Insert temperature**>.
e. Number of cooling degree-days for each day calculated from a base temperature of [**65 deg F**] <**Insert temperature**>.
f. Monthly minimum, maximum, and average outdoor carbon dioxide level.
g. Daily minimum, maximum, and average relative humidity.
h. Daily minimum, maximum, and average barometric pressure.
i. Daily minimum, maximum, and average wind speed and direction.

4. Include annual (12-month) report showing the following:

a. Monthly minimum, maximum, and average outdoor dry-bulb temperature.
b. Monthly minimum, maximum, and average outdoor wet-bulb temperature.
c. Monthly minimum, maximum, and average outdoor dew point temperature.
d. Number of heating degree-days for each month calculated from a base temperature of [**55 deg F**] <**Insert temperature**>.
e. Number of cooling degree-days for each month calculated from a base temperature of [**65 deg F**] <**Insert temperature**>.
f. Annual minimum, maximum, and average outdoor carbon dioxide level.
g. Monthly minimum, maximum, and average relative humidity.
h. Daily minimum, maximum, and average barometric pressure.
i. Daily minimum, maximum, and average wind speed and direction.

Q. Standard Trends:

1. Trend all I/O point present values, set points, and other parameters indicated for trending.
2. Trends shall be associated into groups, and a trend report shall be set up for each group.

3. Trends shall be stored within DDC controller and uploaded to hard drives automatically on reaching [**75**] <**Insert value**> of DDC controller buffer limit, or by operator request, or by archiving time schedule.
4. Preset trend intervals for each I/O point after review with Owner.
5. Trend intervals shall be operator selectable from 10 seconds up to 60 minutes. Minimum number of consecutive trend values stored at one time shall be 100 per variable.
6. When drive storage memory is full, most recent data shall overwrite oldest data.
7. Archived and real-time trend data shall be available for viewing numerically and graphically by operators.

R. Custom Trends: Operator shall be able to define a custom trend log for any I/O point in DDC system.

1. Each trend shall include interval, start time, and stop time.
2. Data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on [**workstation**] [**server**] hard drives.
3. Data shall be retrievable for use in spreadsheets and standard database programs.

S. Programming Software:

1. Include programming software to execute sequences of operation indicated.
2. Include programming routines in simple and easy to follow logic with detailed text comments describing what the logic does and how it corresponds to sequence of operation.

Retain "as follows" option in first subparagraph below to limit the type of programming software to a specific type. Retain "any of the following" option to allow choice to use any programming type. Retain "one of the following" option to allow choice to allow use of just one of multiple programming types indicated. Revise subparagraphs to limit programming options.

3. Programming software shall be [**as follows**] [**any of the following**] [**one of the following**]:

Graphic-based programming is easiest method of programming options indicated and best suited for operators with limited programming experience. Not all DDC system manufacturers offer graphic-based programming. Consult manufacturers.

a. Graphic Based: Programming shall use a library of function blocks made from preprogrammed code designed for DDC control systems.

1) Function blocks shall be assembled with interconnection lines that represent to control sequence in a flowchart.
2) Programming tools shall be viewable in real time to show present values and logical results of each function block.

b. Menu Based: Programming shall be done by entering parameters, definitions, conditions, requirements and constraints.
c. Line by Line and Text Based: Programming shall declare variable types such as local, global, real, integer, and so on, at the beginning of the program. Use descriptive comments frequently to describe programming code.

4. Include means for detecting programming errors and testing software control strategies with a simulation tool before implementing in actual control. Simulation tool may be inherent with programming software or as a separate product.

Retain "Database Management Software" Paragraph below for DDC systems with database requirements that use SQL. Coordinate with other DDC system database requirements indicated.

T. Database Management Software:

1. Where a separate SQL database is used for information storage, DDC system shall include database management software that separates database monitoring and managing functions by supporting multiple separate windows.
2. Database secure access shall be accomplished using standard SQL authentication including ability to access data for use outside of DDC system applications.
3. Database management function shall include summarized information on trend, alarm, event, and audit for the following database management actions:

    a. Backup.
    b. Purge.
    c. Restore.

4. Database management software shall support the following:

    a. Statistics: Display database server information and trend, alarm, event, and audit information on database.
    b. Maintenance: Include method of purging records from trend, alarm, event and audit databases by supporting separate screens for creating a backup before purging, selecting database, and allowing for retention of a selected number of day's data.
    c. Backup: Include means to create a database backup file and select a storage location.
    d. Restore: Include a restricted means of restoring a database by requiring operator to have proper security level.

5. Database management software shall include information of current database activity, including the following:

    a. Ready.
    b. Purging record from a database.
    c. Action failed.
    d. Refreshing statistics.
    e. Restoring database.
    f. Shrinking a database.
    g. Backing up a database.
    h. Resetting Internet information services.
    i. Starting network device manager.
    j. Shutting down the network device manager.
    k. Action successful.

6. Database management software monitoring functions shall continuously read database information once operator has logged on.

7. Include operator notification through on-screen pop-up display and e-mail message when database value has exceeded a warning or alarm limit.
8. Monitoring settings window shall have the following sections:

    a. Allow operator to set and review scan intervals and start times.
    b. E-mail: Allow operator to create and review e-mail and phone text messages to be delivered when a warning or an alarm is generated.
    c. Warning: Allow operator to define warning limit parameters, set reminder frequency and link e-mail message.
    d. Alarm: Allow operator to define alarm limit parameters, set reminder frequency and link e-mail message.
    e. Database Login: Protect system from unauthorized database manipulation by creating a read access and a write access for each of trend, alarm, event and audit databases as well as operator proper security access to restore a database.

9. Monitoring settings taskbar shall include the following informational icons:

    a. Normal: Indicates by color and size, or other easily identifiable means that all databases are within their limits.
    b. Warning: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their warning limit.
    c. Alarm: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their alarm limit.

2.17 OFFICE APPLICATION SOFTWARE

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Include current version of office application software at time of Substantial Completion.

C. Office application software package shall include multiple separate applications and use a common platform for all applications, similar to Microsoft's "Office Professional."

1. Database.
2. E-mail.
3. Presentation.
4. Publisher.
5. Spreadsheet.
6. Word processing.

2.18 MAINTENANCE MANAGEMENT SOFTWARE

Retain this article for Project with rigorous requirements for maintenance management. Consult Owner to discuss requirements for maintenance.

A. Scope:

1. Include complete and functional software-driven maintenance management system. Software shall perform scheduling of preventive maintenance and generation of work orders, for mechanical and electrical equipment and systems.
2. Work orders shall be automatically generated from alarm conditions, run time, and calendar time. Each work order generated shall list parts, tools, craftspeople, and define task to be performed.
3. Work order generated shall be used to schedule a repair or preventive maintenance routine.
4. Work order shall be used to track completion of work, parts used and total cost of repair.
5. A database shall include an inventory tracking system. Work orders generated shall automatically update inventory database to show quantity of tools, repair parts and expendables used for a work order.
6. Work orders and preventive maintenance schedules shall be printed on a dedicated printer assigned solely to maintenance management function.

B. Additional Hardware Requirements:

1. Maintenance management software shall not require additional hardware, except for an additional printer that is dedicated to maintenance management.
2. Maintenance management software shall be integrated into DDC system.

C. Software Requirements:

1. From main menu of maintenance management system, it shall be possible through selection of icons to penetrate to individual functions described below.
2. Work Orders:

   a. Automatically generate work orders initiated from alarm conditions, accumulated run time or calendar time. Work orders generated shall specify a particular task to be accomplished including the labor, material and tools needed to accomplish work.
   b. Include at least two of the following types of work orders:

      1) Corrective and emergency maintenance work orders shall be generated for a specific job or repair for emergency, breakdown, or scheduled work.
      2) Preventive maintenance that are used on a periodic basis to generate preventive maintenance work orders.

   c. Include the following functions:

      1) Work Order Tracking: Perform every function related to processing work orders including creating, approving and initiating work orders, checking their status history and closing or reworking them when appropriate.
      2) Work Requests: Report any problems that require corrective maintenance activity generated by dispatchers and those people designated to request work orders.
      3) Quick Reporting: Report work done on an open work order or a small job.
      4) Work Manager: Specify the type of labor to be applied to a specific work order at specific times. It shall include the capability to dispatch one or more laborers to top-priority jobs on as-needed basis and to interrupt work in progress to reassign labor to higher priority tasks.

d. Reports:

1) Daily Maintenance Schedule by Supervisor: List a schedule of open work orders for a specified date by supervisor.
2) Equipment Cost Roll-up Report: Include a roll-up of equipment costs incurred since the date the report was last run.
3) Delinquent Work Order Report: List open work orders whose target completion date is earlier than the date the report is run.
4) Employee Job Assignments: List labor codes that have job assignments for the specified date.
5) Daily Work Order Assignment: List work orders that have labor assignments for the specified date.
6) Estimated versus Actual Work Order Costs: List a cost summary of outstanding work orders.
7) Open Work Orders Report: List open work orders for locations and equipment.

3. Inventory:

a. Include an inventory tracking system to keep track of stocked, non-stocked and special-order items.
b. Link inventory tracking to database and when items are consumed, as noted on a work order issued by system, inventory of stocked items shall be automatically updated.
c. Include the following functions:

1) Inventory Control: Enter, display, and update information on each inventory item. It shall allow viewing of master inventory records that are independent of storeroom locations or item/location records. Include a screen that lists inventory transactions that move items in or out of inventory or from one storeroom location to another. Minimum information tracked shall include the following:

a) Vendors supply items.
b) Item balances, including the bin and lot level for each storeroom location.
c) Alternative items.

2) Issues and Transfers: Issue stock directly from inventory, with or without a work order. When transfer of stock from one location to another location occurs, provide appropriate adjustments in stock balance record. Include a trace record of stock transfers from one storeroom to another.
3) Item Assembly Structures: Include modeling of equipment with inventory items and building of equipment and location hierarchies.
4) Metered Material Usage:

a) Track usage by a piece of equipment.
b) Record against a standing work order for a selected piece of equipment.

c) Material usage transaction shall be written for each item of material used and be provided as an input to calculation for per unit material consumption report for a piece of equipment.

d. Reports:

1) Inventory Analysis Report: List for a given storeroom location, inventory items analysis information that allows quick identification of which inventory items represent greatest monetary investment for dollar value and rate of turnover.
2) Inventory Cycle Count Report: List for a specified storeroom, inventory items that are due to be cycle-counted, based on cycle-count frequency and last count date.
3) Economic Order Quantity Report: For a given storeroom location, display optimum economic ordering quantity for items in selected results set.
4) Inventory Pick Report: A pick list, by work order for items needed to be pulled from a designated storeroom's inventory for work orders having a target start date of specified date.
5) Suggested Order Report: List inventory items in selected results set that are due to be recorded, for a specified storeroom location, based on the following calculation: Suggest a reorder if current balance minus reserve quantity plus on-order quantity is less than reorder point.
6) Reorder Point Report: List selected set of items and optimum minimum level to have in stock based on demand, lead delivery time and a reserve safety stock.
7) Inventory Valuation Report: Gives an accounting of cost of current inventory, for inventory records in a designated storeroom location.
8) Item Order Status: Lists items on order.
9) List of Expired Items: Lists expired lot items in a storeroom. Report shall include item number, description, expiration date, bin number, lot number, manufacturer lot number, and quantity of expired items in that lot and bin.
10) Item Availability at All Locations: Lists alternative storeroom locations for selected items.
11) Where Used Report: List equipment on which item is recorded as being used.

4. Equipment:

a. Include equipment and location records; establish relationships between equipment, between locations, and between equipment and locations; track maintenance costs; and enter and review meter readings.
b. Include the following functions:

1) Equipment: Store equipment numbers and corresponding information including equipment class, location, vendor, up/down status and maintenance costs for each piece of equipment. Include building of equipment assemblies. Equipment assemblies hierarchical ordering shall be provided for arrangement of buildings, departments, equipment and sub-assemblies.
2) Operating Locations: Facilitate creation of records for operating locations of equipment, and track equipment that is used in multiple locations. In

addition, allow hierarchical organization of equipment operating in facility by means of grouping equipment locations into areas of responsibility.

3) Failure Codes: Develop and display failure hierarchies to acquire an accurate history of types of failures that affect equipment and operating locations.
4) Condition Monitoring: Display time related or limit measurements recorded for a piece of equipment. It shall be possible to generate work orders from this screen and to take immediate action on problem conditions.

c. Reports:

1) Availability Statistic by Location: List equipment availability by location over a user-specified time period.
2) Equipment Failure Summary: List total number of failures by problem code for a piece of equipment for a specified time period.
3) Detailed Equipment Failure Report by Equipment: List of failure reports for the current piece of equipment for a specified time period.
4) Equipment Hierarchy Report: List of equipment.
5) Equipment History Graphs: Include a graphical report in histogram format that displays equipment breakdown history over a specified period.
6) Equipment Measurement Report: Tabular listing and description of each measurement point for a piece of equipment and the history of measurements taken for that point.
7) Maintenance Cost by Equipment: List of transactions costs for elected equipment in the specified date range.
8) Failure Count by Equipment: Graphically report the number of failures for each piece of equipment showing number of failures for each piece of equipment over a specified time period, occurrence of each problem code within set of failures and failures by problem code.
9) Failure Analysis Graphs: Graphically report number of failures for each piece of equipment over a specified time period, number of occurrences of each problem code within set of failures and failures by problem code.
10) Failure Code Hierarchy Report: List of failure codes in each level of the failure hierarchy.
11) Location Failure Summary: A summary for each selected location of failures reported and any hierarchy level locations for specified time period.
12) Failure Summary by Location: A summary of failures for the selected location and their subordinate locations that are part of the hierarchical system.
13) Detailed Failure Report by Location: List all failures for selected location and its subordinate locations that are part of a hierarchical system.
14) Maintenance Cost by System: List of total costs reported in a given date range for locations in selected hierarchical system.
15) Location Hierarchy Report: Lists member locations of a hierarchical system displayed in hierarchical fashion.

5. Purchasing:

a. Include preparation and generation of purchase requisitions and purchase orders; to report receipt of both items and services, match invoices with purchase orders and receipts and define and convert foreign currencies.

b. Include the following functions:

1) Purchase Requisition: Create and process purchase requisitions for items and services.
2) Purchase Orders: Create and process purchase orders for items and services from scratch or from purchase requisitions. Record receipts of items and services.
3) Invoices: Include functionality to match purchase orders with invoices and receipts. It shall also be possible to match a service receipt to an invoice. Project for entering of an invoice for bills that do not require purchase orders or receipts.
4) Currency Management: Define currencies and specify exchange rates. Include preparation of purchase requisitions and purchase orders in currency of vendor, while tracking costs in systems base currency.

c. Reports:

1) Invoice Approval Report: Include an approval form for entered invoices.
2) Inventory Receipts Register: List purchase orders and inventory received for the user-specified time frame.
3) Direct Purchase Back-Order Report: List of items ordered as a direct purchase not received by the required delivery date.
4) Standard Purchase Order: A printing of primary purchase order with vendors shipping information, and items purchased.
5) Purchase Order Status Report: List of purchase orders whose status has changed during a certain time period.
6) Standard Purchase Requisition: A printing of primary purchase requisition, including vendor name and shipping information.

6. Job Plans:

a. Include creation of a detailed description of work to be performed by a work order. The job plan shall contain operations, procedures and list of estimated material, labor and tools required for work.

7. Labor:

a. Store information on employees, contractors, and crafts and include the following functions:

1) Labor: Create, modify and view employee records. Employee records shall contain pay rate, overtime worked, overtime refused, specials skills and certifications.
2) Crafts: Create, modify and view craftspeople records.
3) Labor Reporting: Report labor usage by employee or craft externally from the work orders module.

b. Reports:

1) Employee Attendance Analysis: List of planned attendance, actual attendance, vacation and sick time in hours as a percentage of planned attendance for selected employees for specified time period.
2) Labor Productivity Analysis: List of actual labor hours by labor report category showing each by percentage.
3) Labor Availability versus Commitments by Crafts: A graphical report that details available labor hours versus committed work order hours by craft and day.

8. Calendars:

a. Establish calendar records indicating working time for equipment, location, craft, and labor records.

9. Resources:

a. Include entry and retrieval of data associated with resources required to maintain facility and to include the following functions:

1) Companies: Establish and update data on vendors and other companies.
2) Tools: Create and maintain information on the tools used on jobs. The information contained within this module shall be available to job plans and work orders.
3) Service Contracts: Specify information on service contracts with vendors or manufacturers.

10. Custom Applications:

a. Include creation of customized database tables and application screens that supplement functions specified.

11. Setup:

a. Include configuration of database, security and setup applications.
b. Perform the following functions:

1) Reports and Other Applications: Register reports and other applications for use within system.
2) Documents: Enter, track and link information from Drawings to equipment and inventory items.
3) Chart of Accounts: Add or modify accounts; set up financial periods; enter inventory accounts, company accounts, and resource recovery accounts; and define tax codes and rates.
4) Signature Security: Establish each user's access rights to modules, applications, screens and options.
5) Database Configuration: Customize database, including adjusting field lengths and modifying data types.
6) Application Setup: Change position of icons and menu items on the main menu screen.
7) Application Launching: Allow for connecting of third-party applications to data fields and push buttons.

12. Utilities:

a. Include utilities module that allows system administrator to customize system and to maintain database.
b. Include the following functions:

1) Interactive SQL: Include access to database for database management functions of import/export and backup.
2) Edit Windows: Display a dialog box to customize an application.
3) Archive Data: Remove records from database and store them for future reference.

D. Documentation:

1. Include complete documentation for the system consisting of a User Manual and Systems Administrator Guide.
2. User Manual shall describe how to use each application module and screen with step-by-step instructions detailing entry and retrieval of data for functions specified.
3. Include a step-by-step description of how each report is defined and retrieved.
4. Bind documentation and clearly title it indicating volume number and use.

Retain "ASHRAE 135 Gateways" Article below for DDC systems using ASHRAE 135 protocol.

2.19 ASHRAE 135 GATEWAYS

Gateways require a thorough understanding of their application. Use caution when connecting non-BACnet to BACnet protocol. It may be more practical to select products that are already "BACnet ready." Research gateway manufacturers for price, options, and performance. Design for each gateway should include an interoperability schedule showing each point or event on non-BACnet side that BACnet "client" will read, and each parameter that BACnet network will write to for BACnet services, or BACnet BIBBs, defined in ASHRAE 135, Annex K.

A. Include BACnet communication ports, whenever available as an equipment OEM standard option, for integration via a single communication cable. BACnet-controlled plant equipment includes, but is not limited to, boilers, chillers, <**Insert equipment,**> and variable-speed drives.

B. Include gateways to connect BACnet to legacy systems, existing non-BACnet devices, and existing non-BACnet DDC-controlled equipment, only when specifically requested and approved by Owner.

C. Include with each gateway an interoperability schedule showing each point or event on legacy side that BACnet "client" will read, and each parameter that BACnet network will write to. Describe this interoperability of BACnet services, or BIBBs, defined in ASHRAE 135, Annex K.

D. Gateway Minimum Requirements:

1. Read and view all readable object properties on non-BACnet network to BACnet network and vice versa where applicable.

2. Write to all writeable object properties on non-BACnet network from BACnet network and vice versa where applicable.
3. Include single-pass (only one protocol to BACnet without intermediary protocols) translation from non-BACnet protocol to BACnet and vice versa.
4. Comply with requirements of Data Sharing Read Property, Data Sharing Write Property, Device Management Dynamic Device Binding-B, and Device Management Communication Control BIBBs according to ASHRAE 135.
5. Hardware, software, software licenses, and configuration tools for operator-to-gateway communications.
6. Backup programming and parameters on CD media and the ability to modify, download, backup, and restore gateway configuration.

Retain "ASHRAE 135 Protocol Analyzer" Article below for DDC systems using ASHRAE 135 protocol.

2.20 ASHRAE 135 PROTOCOL ANALYZER

Retain protocol analyzer after consulting Owner and confirming operators require it, as it takes a moderate level of skill and knowledge to use.

Protocol analyzer is typically software for connecting a computer to any ASHRAE 135 network for use in gathering basic system information. It is most useful for integration projects with poorly documented systems and where different manufacturers' products reside on same network.

A. Analyzer and required cables and fittings for connection to ASHRAE 135 network.

B. Analyzer shall include the following minimum capabilities:

1. Capture and store to a file data traffic on all network levels.
2. Measure bandwidth usage.
3. Filtering options with ability to ignore select traffic.

2.21 CEA-709.1-C NETWORK HARDWARE

Retain this article for DDC systems using LON protocol.

A. Routers:

1. Network routers, including routers configured as repeaters, shall comply with requirements of CEA-709.1-C and include connection between two or more CEA-709.3 TP/FT-10 channels or between two or more CEA-709.3 TP/FT-10 channels and a TP/XF-1250 channel.
2. IP Routers:

a. Perform layer three routing of CEA-709.1-C packets over an IP network according to CEA-852-B.
b. Include appropriate connection to the IP network and connections to CEA-709.3 TP/FT-10 or TP/XF-1250 network.

c. Support the Dynamic Host Configuration Protocol for IP configuration and use of an CEA-852-B Configuration Server (for CEA-852-B configuration), but shall not rely on these services for configuration.
d. Capable of manual configuration via a console RS-232 port.

B. Gateways:

1. Perform bidirectional protocol translation from one non-CEA-709.1-C protocol to CEA-709.1-C.
2. Incorporate a network connection to a TP/FT-10 network according to CEA-709.3 and a connection for a non-CEA-709.1-C network.

2.22 WIRELESS ROUTERS FOR OPERATOR INTERFACE

If wireless routers are required, retain one or both wireless router types: single band and dual band. If retaining both types, indicate on Drawings or in an application article describing application of each type on Project.

A. Single-Band Wireless Routers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description: High-speed router with integral Ethernet ports.
3. Technology: IEEE 802.11n; [**2.4**] <**Insert number**>-GHz speed band.
4. Speed: Up to [**300**] <**Insert number**> Mbps.
5. Compatibility: IEEE 802.11n/g/b/a wireless devices.
6. Ethernet Ports: Four, gigabit (1000 Mbps).
7. Wireless Security: Wi-Fi Protected Access (WPA) and WPA2 according to IEEE 802.11i.

B. Dual-Band Wireless Routers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description: High-speed, dual-band router with integral Ethernet ports and USB port.
3. Technology: IEEE 802.11n; 2.4- and 5-GHz speed bands.
4. Speed: Up to [**300**] <**Insert number**> Mbps on 2.4-GHz band and up to [**450**] <**Insert number**> Mbps on 5-GHz band.
5. Compatibility: IEEE 802.11n/g/b/a wireless devices.
6. Ethernet Ports: Four, gigabit (1000 Mbps).
7. USB Port: One, USB 2.0 or 3.0.
8. Wireless Security: Wi-Fi Protected Access (WPA) and WPA2 according to IEEE 802.11i.

2.23 DDC CONTROLLERS

A. DDC system shall consist of a combination of network controllers, programmable application controllers and application-specific controllers to satisfy performance requirements indicated.

B. DDC controllers shall perform monitoring, control, energy optimization and other requirements indicated.

C. DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.

D. Each DDC controller shall be capable of full and complete operation as a completely independent unit and as a part of a DDC system wide distributed network.

E. Environment Requirements:

1. Controller hardware shall be suitable for the anticipated ambient conditions.
2. Controllers located in conditioned space shall be rated for operation at [**32 to 120 deg F**] <**Insert temperature range**>.
3. Controllers located outdoors shall be rated for operation at [**40 to 150 deg F**] <**Insert temperature range**>.

F. Power and Noise Immunity:

1. Controller shall operate at 90 to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent of nominal voltage.
2. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within36 inches of enclosure.

Retain "DDC Controller Spare Processing Capacity" Paragraph below to require spare processing capacity for future growth.

G. DDC Controller Spare Processing Capacity:

1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:

a. Network Controllers: [**50**] [**60**] [**70**] <**Insert value**> percent.
b. Programmable Application Controllers: Not less than [**60**] [**70**] [**80**] <**Insert number**> percent.
c. Application-Specific Controllers: Not less than [**70**] [**80**] [**90**] <**Insert number**> percent.

2. Memory shall support DDC controller's operating system and database and shall include the following:

a. Monitoring and control.
b. Energy management, operation and optimization applications.
c. Alarm management.
d. Historical trend data of all connected I/O points.
e. Maintenance applications.
f. Operator interfaces.
g. Monitoring of manual overrides.

Retain "DDC Controller Spare I/O Point Capacity" Paragraph below to require spare point capacity for future growth.

H. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:

1. Network Controllers:

   a. [**10**] [**20**] <**Insert number**> percent of each AI, AO, BI, and BO point connected to controller.
   b. Minimum Spare I/O Points per Controller:

      1) AIs: [**Two**] [**Three**] <**Insert number**>.
      2) AOs: [**Two**] [**Three**] <**Insert number**>.
      3) BIs: [**Three**] [**Five**] <**Insert number**>.
      4) BOs: [**Three**] [**Five**] <**Insert number**>.

2. Programmable Application Controllers:

   a. [**10**] [**20**] <**Insert number**> percent of each AI, AO, BI, and BO point connected to controller.
   b. Minimum Spare I/O Points per Controller:

      1) AIs: [**Two**] [**Three**] <**Insert number**>.
      2) AOs: [**Two**] [**Three**] <**Insert number**>.
      3) BIs: [**Three**] [**Five**] <**Insert number**>.
      4) BOs: [**Three**] [**Five**] <**Insert number**>.

3. Application-Specific Controllers:

   a. [**10**] <**Insert number**> percent of each AI, AO, BI, and BO point connected to controller.
   b. Minimum Spare I/O Points per Controller:

      1) AIs: [**One**] [**Two**] <**Insert number**>.
      2) AOs: [**One**] [**Two**] <**Insert number**>.
      3) BIs: [**One**] [**Two**] <**Insert number**>.
      4) BOs: [**One**] [**Two**] <**Insert number**>.

I. Maintenance and Support: Include the following features to facilitate maintenance and support:

1. Mount microprocessor components on circuit cards for ease of removal and replacement.
2. Means to quickly and easily disconnect controller from network.
3. Means to quickly and easily access connect to field test equipment.
4. Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to network.

J. General Requirements for CEA-709.1-C DDC Controllers:

1. Controllers shall be LonMark certified.
2. Distinguishable and accessible switch, button, or pin, when pressed shall broadcast its 48-bit Node ID and Program ID over network.
3. TP/FT-10 transceiver according to CEA-709.3 and connections for TP/FT-10 control network wiring.
4. TP/XF-1250 transceiver according to CEA-709.3 and connections for TP/XF-1250 control network wiring.
5. Communicate using CEA-709.1-C protocol.

6. Controllers configured into subnets, as required, to comply with performance requirements indicated.
7. Network communication through LNS network management and database standard for CEA-709.1-C network devices.
8. Locally powered, not powered through network connection.
9. Functionality required to support applications indicated, including, but not limited to, the following:

    a. Input and outputs indicated and as required to support sequence of operation and application in which it is used. SNVTs shall have meaningful names identifying the value represented by an SNVT. Unless an SNVT of an appropriate engineering type is unavailable, all network variables shall be of an SNVT with engineering units appropriate to value the variable represents.
    b. Configurable through SCPTs defined in LonMark SCPT List, operator-defined UCPTs, network configuration inputs (NCIs) of an SNVT type defined in LonMark SNVT List, NCIs of an operator-defined network variable type, or hardware settings on controller itself for all settings and parameters used by application in which it is used.

10. Programmable controllers shall conform to LonMark Interoperability Guidelines and have LonMark certification.

K. Input and Output Point Interface:

1. Hardwired input and output points shall connect to network, programmable application and application-specific controllers.
2. Input and output points shall be protected so shorting of point to itself, to another point, or to ground will not damage controller.
3. Input and output points shall be protected from voltage up to 24 V of any duration so that contact will not damage controller.
4. AIs:

    a. AIs shall include monitoring of low-voltage (zero- to 10-V dc), current (4 to 20 mA) and resistance signals from thermistor and RTD sensors.
    b. AIs shall be compatible with, and field configurable to, sensor and transmitters installed.
    c. Controller AIs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of [**8**] [**12**] <**Insert value**> bits or better to comply with accuracy requirements indicated.
    d. Signal conditioning including transient rejection shall be provided for each AI.
    e. Capable of being individually calibrated for zero and span.
    f. Incorporate common-mode noise rejection of at least 50 dB from zero to 100 Hz for differential inputs, and normal-mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10000 ohms.

5. AOs:

    a. Controller AOs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of [**8**] [**12**] <**Insert value**> bits or better to comply with accuracy requirements indicated.

b. Output signals shall have a range of [**4 to 20 mA dc**] [**or**] [**zero- to 10-V dc**] as required to include proper control of output device.
c. Capable of being individually calibrated for zero and span.
d. AOs shall not exhibit a drift of greater than 0.4 percent of range per year.

6. BIs:

a. Controller BIs shall accept contact closures and shall ignore transients of less than 5-ms duration.
b. Isolation and protection against an applied steady-state voltage of up to 180-V ac peak.
c. BIs shall include a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against effects of contact bounce and noise.
d. BIs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.
e. Pulse accumulation input points shall comply with all requirements of BIs and accept up to 10 pulses per second for pulse accumulation. Buffer shall be provided to totalize pulses. Pulse accumulator shall accept rates of at least 20 pulses per second. The totalized value shall be reset to zero on operator's command.

7. BOs:

a. Controller BOs shall include relay contact closures or triac outputs for momentary and maintained operation of output devices.

1) Relay contact closures shall have a minimum duration of 0.1 second. Relays shall include at least 180 V of isolation. Electromagnetic interference suppression shall be provided on all output lines to limit transients to non-damaging levels. Minimum contact rating shall be 1 A at 24-V ac.
2) Triac outputs shall include at least 180 V of isolation. Minimum contact rating shall be 1 A at 24-V ac.

b. BOs shall include for two-state operation or a pulsed low-voltage signal for pulse-width modulation control.
c. BOs shall be selectable for either normally open or normally closed operation.
d. Include tristate outputs (two coordinated BOs) for control of three-point floating-type electronic actuators without feedback.
e. Limit use of three-point floating devices to VAV terminal unit control applications, [**and other applications indicated on Drawings,**] <**Insert applications**>. Control algorithms shall operate actuator to one end of its stroke once every [**12**] [**24**] <**Insert time**> hours for verification of operator tracking.

2.24 NETWORK CONTROLLERS

A. General Network Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.

3. Controller shall have enough memory to support its operating system, database, and programming requirements.
4. Data shall be shared between networked controllers and other network devices.
5. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
6. Controllers [**that perform scheduling**]shall have a real-time clock.
7. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
8. Controllers shall be fully programmable.

B. Communication:

1. Network controllers shall communicate with other devices on DDC system [**Level one**] <**Insert level**> network.
2. Network controller also shall perform routing if connected to a network of programmable application and application-specific controllers.

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation[**or mobile device**].

Retain "Local Keypad and Display" Subparagraph below to require a local keypad and display. Requirement adds cost and is unnecessary for most applications.

2. Local Keypad and Display:

   a. Equip controller with local keypad and digital display for interrogating and editing data.
   b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least [**72**] [**96**] <**Insert number**> hours.

2.25 PROGRAMMABLE APPLICATION CONTROLLERS

A. General Programmable Application Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. Controller shall have enough memory to support its operating system, database, and programming requirements.
3. Data shall be shared between networked controllers and other network devices.

4. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
5. Controllers [**that perform scheduling**]shall have a real-time clock.
6. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
7. Controllers shall be fully programmable.

B. Communication:

1. Programmable application controllers shall communicate with other devices on network.

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation[**or mobile device**].

Retain "Local Keypad and Display" Subparagraph below to require a local keypad and display. Requirement adds cost and is unnecessary for most applications.

2. Local Keypad and Display:

a. Equip controller with local keypad and digital display for interrogating and editing data.
b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.26 APPLICATION-SPECIFIC CONTROLLERS

A. Description: Microprocessor-based controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. Controllers are not fully user-programmable but are configurable and customizable for operation of equipment they are designed to control.

1. Capable of standalone operation and shall continue to include control functions without being connected to network.
2. Data shall be shared between networked controllers and other network devices.

B. Communication: Application-specific controllers shall communicate with other application-specific controller and devices on network, and to programmable application and network controllers.

C. Operator Interface: Controller shall be equipped with a service communications port for connection to a portable operator's workstation.[**Connection shall extend to port on space temperature sensor that is connected to controller.**]

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall use nonvolatile memory and maintain all BIOS and programming information in event of power loss.

2.27 CONTROLLER SOFTWARE

A. General Controller Software Requirements:

1. Software applications shall reside and operate in controllers. Editing of applications shall occur at operator workstations.
2. I/O points shall be identified by up to [**30**] <**Insert number**>-character point name and up to [**16**] <**Insert number**>-character point descriptor. Same names shall be used at operator workstations.
3. Control functions shall be executed within controllers using DDC algorithms.
4. Controllers shall be configured to use stored default values to ensure fail-safe operation. Default values shall be used when there is a failure of a connected input instrument or loss of communication of a global point value.

B. Security:

1. Operator access shall be secured using individual security passwords and user names.
2. Passwords shall restrict operator to points, applications, and system functions as assigned by system manager.
3. Operator log-on and log-off attempts shall be recorded.
4. System shall protect itself from unauthorized use by automatically logging off after last keystroke. The delay time shall be operator-definable.

C. Scheduling: Include capability to schedule each point or group of points in system. Each schedule shall consist of the following:

1. Weekly Schedule:

   a. Include separate schedules for each day of week.
   b. Each schedule should include the capability for start, stop, optimal start, optimal stop, and night economizer.
   c. Each schedule may consist of up to 10 events.
   d. When a group of objects are scheduled together, include capability to adjust start and stop times for each member.

2. Exception Schedules:

a. Include ability for operator to designate any day of the year as an exception schedule.
b. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by regular schedule for that day of week.

3. Holiday Schedules:

a. Include capability for operator to define up to 99 special or holiday schedules.
b. Schedules may be placed on scheduling calendar and will be repeated each year.
c. Operator shall be able to define length of each holiday period.

D. System Coordination:

1. Include standard application for proper coordination of equipment.
2. Application shall include operator with a method of grouping together equipment based on function and location.
3. Group may then be used for scheduling and other applications.

E. Binary Alarms:

1. Each binary point shall be set to alarm based on operator-specified state.
2. Include capability to automatically and manually disable alarming.

F. Analog Alarms:

1. Each analog object shall have both high and low alarm limits.
2. Alarming shall be able to be automatically and manually disabled.

G. Alarm Reporting:

1. Operator shall be able to determine action to be taken in event of an alarm.
2. Alarms shall be routed to appropriate operator workstations based on time and other conditions.
3. Alarm shall be able to start programs, print, be logged in event log, generate custom messages, and display graphics.

H. Remote Communication:

1. System shall have ability to dial out in the event of an alarm.

I. Electric Power Demand Limiting:

1. Demand-limiting program shall monitor building or other operator-defined electric power consumption from signals connected to electric power meter or from a watt transducer or current transformer.
2. Demand-limiting program shall predict probable power demand such that action can be taken to prevent exceeding demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.

3. Demand reduction shall be accomplished by the following means:

    a. Reset air-handling unit supply temperature set points.
    b. Reset space temperature set points.
    c. De-energize equipment based on priority.

4. Demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which electric power service provider computes demand charges.
5. Include demand-limiting prediction and control for any individual meter monitored by system or for total of any combination of meters.
6. Include means operator to make the following changes online:

    a. Addition and deletion of loads controlled.
    b. Changes in demand intervals.
    c. Changes in demand limit for meter(s).
    d. Maximum shutoff time for equipment.
    e. Minimum shutoff time for equipment.
    f. Select rotational or sequential shedding and restoring.
    g. Shed and restore priority.

7. Include the following information and reports, to be available on an hourly, daily, weekly, monthly and annual basis:

    a. Total electric consumption.
    b. Peak demand.
    c. Date and time of peak demand.
    d. Daily peak demand.

J. Maintenance Management: System shall monitor equipment status and generate maintenance messages based on operator-designated run-time, starts, and calendar date limits.

K. Sequencing: Include application software based on sequences of operation indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.

L. Control Loops:

1. Support any of the following control loops, as applicable to control required:

    a. Two-position (on/off, open/close, slow/fast) control.
    b. Proportional control.
    c. Proportional plus integral (PI) control.
    d. Proportional plus integral plus derivative (PID) control.

        1) Include PID algorithms with direct or reverse action and anti-windup.
        2) Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.
        3) Controlled variable, set point, and PID gains shall be operator-selectable.

    e. Adaptive (automatic tuning).

M. Staggered Start: Application shall prevent all controlled equipment from simultaneously restarting after a power outage. Order which equipment (or groups of equipment) is started, along with the time delay between starts, shall be operator-selectable.

N. Energy Calculations:

1. Include software to allow instantaneous power or flow rates to be accumulated and converted to energy usage data.
2. Include an algorithm that calculates a sliding-window average (rolling average). Algorithm shall be flexible to allow window intervals to be operator specified (such as 15, 30, or 60 minutes).
3. Include an algorithm that calculates a fixed-window average. A digital input signal shall define start of window period (such as signal from utility meter) to synchronize fixed-window average with that used by utility.

O. Anti-Short Cycling:

1. BO points shall be protected from short cycling.
2. Feature shall allow minimum on-time and off-time to be selected.

P. On and Off Control with Differential:

1. Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.
2. Algorithm shall be direct- or reverse-acting and incorporate an adjustable differential.

Q. Run-Time Totalization:

1. Include software to totalize run-times for all BI [**and BO**]points.
2. A high run-time alarm shall be assigned, if required, by operator.

2.28 ENCLOSURES

A. General Enclosure Requirements:

1. House each controller and associated control accessories in a [**single**]enclosure. Enclosure shall serve as central tie-in point for control devices such as switches, transmitters, transducers, power supplies and transformers.
2. Do not house more than one controller in a single enclosure.
3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.

Retain first subparagraph below for windows in enclosure doors.

4. Equip doors of enclosures housing controllers and components with analog or digital displays with windows to allow visual observation of displays without opening enclosure door.

Retain any of first two subparagraphs below to restrict enclosure size.

5. Individual wall-mounted single-door enclosures shall not exceed [**36 inches**] <**Insert dimension**> wide and [**48 inches**] [**60 inches**] <**Insert dimension**> high.

6. Individual wall-mounted double-door enclosures shall not exceed [**60 inches**] <**Insert dimension**> wide and [**36 inches**] <**Insert dimension**> high.

Retain first subparagraph below to allow freestanding enclosures.

7. Freestanding enclosures shall not exceed [**48 inches**] <**Insert dimension**> wide and [**72 inches**] <**Insert dimension**> high.
8. Include wall-mounted enclosures with brackets suitable for mounting enclosures to wall or freestanding support stand as indicated.
9. Supply each enclosure with a complete set of as-built schematics, tubing, and wiring diagrams and product literature located in a pocket on inside of door.[**For enclosures with windows, include pocket on bottom of enclosure.**]

B. Internal Arrangement:

1. Internal layout of enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage and low-voltage electrical and electronic products.
4. Factory or shop install products, tubing, cabling and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks.
6. Include spare terminals, equal to not less than [**10**] [**20**] <**Insert number**> percent of used terminals.
7. Include spade lugs for stranded cable and wire.
8. Install a maximum of two wires on each side of a terminal.
9. Include enclosure field power supply with a toggle-type switch located at entrance inside enclosure to disconnect power.

Retain first subparagraph below for enclosure-mounted receptacle.

10. Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
11. Mount products within enclosure on removable internal panel(s).
12. Include products mounted in enclosures with engraved, laminated phenolic nameplates (black letters on a white background). The nameplates shall have at least 1/4-inch-high lettering.
13. Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
14. Label each end of cable, wire and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
15. Size enclosure internal panel to include at least [**25**] <**Insert number**> percent spare area on face of panel.

C. Environmental Requirements:

1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.
2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction and wind) on enclosure.

3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.
4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.
5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.
6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

D. Wall-Mounted, NEMA 250, Type 1:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Enclosure shall be NRTL listed according to UL 50 or UL 50E.
3. Construct enclosure of steel, not less than:

    a. Enclosure size less than 24 in.: [**0.053 in.**] [**or**] [**0.067 in.**] thick.
    b. Enclosure size 24 in. and larger: [**0.067 in.**] [**or**] [**0.093 in.**] thick.

4. Finish enclosure inside and out with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Exterior color shall be [**white**] [**ANSI 61 gray**] [**selected by Architect**] [**manufacturer's standard**] <**Insert color**>.
    b. Interior color shall be [**white**] [**ANSI 61 gray**] [**manufacturer's standard**].

5. Hinged door full size of front face of enclosure and supported using:

    a. Enclosures sizes less than 36 in. tall: Multiple butt hinges.
    b. Enclosures sizes 36 in. tall and larger: Continuous piano hinges.

6. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Size less than 24 in.: [**Solid**] [**or**] [**Perforated**] steel, 0.053 in. thick.
    b. Size 24 in. and larger: Solid [**aluminum, 0.10 in.**] [**or**] [**steel, 0.093 in.**] thick.

7. Internal panel mounting hardware, grounding hardware and sealing washers.
8. Grounding stud on enclosure body.
9. Thermoplastic pocket on inside of door for record Drawings and Product Data.

E. Wall Mounted NEMA 250, Types 4 and 12:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Enclosure shall be NRTL listed according to UL 508A.
3. Seam and joints are continuously welded and ground smooth.
4. Where recessed enclosures are indicated, include enclosures with face flange for flush mounting.

5. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
6. Single-door enclosure sizes up to 60 inches tall by 36 inches wide.
7. Double-door enclosure sizes up to 36 inches tall by 60 inches wide.
8. Construct enclosure of steel, not less than the following:

    a. Size Less Than 24 Inches: [**0.053 inch**] [**or**] [**0.067 inch**] thick.
    b. Size 24 Inches and Larger: 0.067 inch thick.

9. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Exterior color shall be [**white**] [**ANSI 61 gray**] [**as selected by Architect**] [**manufacturer's standard**] <**Insert color**>.
    b. Interior color shall be [**white**] [**ANSI 61 gray**] [**manufacturer's standard**].

10. Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.

    a. Sizes through 24 Inches Tall: Two hinges.
    b. Sizes between 24 Inches through 48 Inches Tall: Three hinges.
    c. Sizes Larger 48 Inches Tall: Four hinges.

11. Double-door enclosures with overlapping door design to include unobstructed full-width access.

    a. Single-door enclosures 48 inches and taller, and all double-door enclosures, with three-point (top, middle and bottom) latch system.

12. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Size Less Than 24 Inches: [**Solid**] [**or**] [**perforated**] steel, 0.053 inch thick.
    b. Size 24 Inches and Larger: Solid [**aluminum, 0.10 inch**] [**or**] [**steel, 0.093 inch**] thick.

13. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
14. Grounding stud on enclosure body.
15. Thermoplastic pocket on inside of door for record Drawings and Product Data.

F. Wall-Mounted, NEMA 250, Type 4X SS:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Enclosure shall be NRTL listed according to UL 508A.
3. Seam and joints are continuously welded and ground smooth.
4. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
5. Construct enclosure of [**Type 304**] [**Type 316L**] stainless steel, not less than the following:

    a. Size Less Than 24 Inches: 0.053 inch thick.

b. Size 24 Inches and Larger: 0.067 inch thick.

6. Outside body and door of enclosure with brushed No. 4 finish.

Retain one of first two subparagraphs below for door hinge choices.

7. Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.

   a. Sizes through 24 InchesTall: Two hinges.
   b. Sizes between 24 Inchesthrough 48 InchesTall: Three hinges.
   c. Sizes Larger 48 InchesTall: Four hinges.

8. Corner-formed door, full size of enclosure face, supported using continuous piano hinge full length of door.

Retain first subparagraph below for upgraded door latching system.

9. Doors fitted with three-point (top, middle, and bottom) latch system with single, heavy-duty, liquid-tight Type 316 stainless-steel handle with integral locking mechanism.
10. Removable internal panel shall be 0.093-inch solid steel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
11. Internal panel mounting studs and hardware, grounding hardware, and sealing washers.
12. Install corrosion-resistant polyester vent drain in a stainless-steel sleeve at the bottom of enclosure.
13. Include enclosure with stainless-steel mounting brackets.

G. Freestanding, NEMA 250, Type 1:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Enclosure shall be NRTL listed according to UL 508A.
3. Seam and joints are continuously welded and ground smooth.
4. Externally formed body flange around perimeter of enclosure face.
5. Single-door enclosure sizes up to 84 inches tall by 36 inches wide.
6. Double-door enclosure sizes up to 84 inches tall by 72 inches wide.
7. Construct enclosure of steel, not less than 0.067 inch thick.
8. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

   a. Exterior color shall be [**white**] [**ANSI 61 gray**] [**as selected by Architect**] [**manufacturer's standard**] <**Insert color**>.
   b. Interior color shall be [**white**] [**ANSI 61 gray**] [**manufacturer's standard**].

9. Corner-formed flush door, full size of enclosure face, supported using four concealed hinges with easily removable hinge pins.
10. Double-door enclosures with overlapping door design to include unobstructed full-width access.
11. Doors with three-point (top, middle, and bottom) latch system with single heavy-duty handle and integral locking mechanism.
12. Removable back covers.
13. Removable solid steel internal panel, 0.093 inch thick, with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
14. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.

15. Grounding stud on enclosure body.
16. Thermoplastic pocket on inside of door for record Drawings and Product Data.
17. Nominal 4-inch-tall integral lifting base, not less than 0.123 inch thick, with predrilled holes for attachment to mounting surface.
18. Each top end of enclosure fitted with lifting tabs, not less than 0.172 inch thick.
19. Internal rack-mount shelves and angles as required by application.

H. Freestanding, NEMA 250, Types 4 and 12:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Enclosure shall be NRTL listed according to UL 508A.
3. Seam and joints are continuously welded and ground smooth.
4. Externally formed body flange around perimeter of enclosure face.
5. Type 12 Enclosure Sizes:

    a. Single-door enclosure sizes up to 90 inches tall by 36 inches wide.
    b. Double-door enclosure sizes up to 90 inches tall by 72 inches wide.

6. Type 4 Enclosure Sizes:

    a. Single-door enclosure sizes up to 72 inches tall by 36 inches wide.

7. Construct enclosure of steel, not less than 0.093 inch thick.
8. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Exterior color shall be [**white**] [**ANSI 61 gray**] [**as selected by Architect**] [**manufacturer's standard**] <**Insert color**>.
    b. Interior color shall be [**white**] [**ANSI 61 gray**] [**manufacturer's standard**].

9. Corner-formed door with continuous perimeter oil-resistant gasket supported using continuous piano hinge full length of door.
10. Doors fitted with three-point (top, middle, and bottom) latch system with latching rod rollers and single, heavy-duty oil-tight handle with integral locking mechanism.
11. Removable solid steel internal panel, 0.093 inch thick, with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
12. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
13. Grounding stud on enclosure body.
14. Thermoplastic pocket on inside of door for record Drawings and Product Data.
15. Top of enclosure fitted with no fewer than two lifting eyes.
16. Internal rack-mount shelves and angles as required by application.

I. Accessories:

1. Electric Heater:

    a. Aluminum housing with brushed finish.
    b. Thermostatic control with adjustable set point from zero to 100 deg F.
    c. Capacity: 100, 200, 400, and 800 W as required by application.

d. Fan draws cool air from bottom of enclosure and passes air across thermostat and heating elements before being released into enclosure cavity. Heated air is discharged through the top of heater.

2. Ventilation Fans, Filtered Intake and Exhaust Grilles:

a. Number and size of fans, filters and grilles as required by application.
b. Compact cooling fans engineered for 50,000 hours of continuous operation without lubrication or service.
c. Fans capable of being installed on any surface and in any position within enclosure for spot cooling or air circulation.
d. Thermostatic control with adjustable set point from 32 to 140 deg F.
e. Airflow Capacity at Zero Pressure:

1) 4-Inch Fan: 100 cfm.
2) 6-Inch Fan: 240 cfm.
3) 10-Inch Fan: 560 cfm.

f. Maximum operating temperature of 158 deg F.
g. 4-inch fan thermally protected and provided with permanently lubricated ball-bearings.
h. 6- and 10-inch fans with ball-bearing construction and split capacitor motors thermally protected to avoid premature failure.
i. Dynamically balanced impellers molded from polycarbonate material.
j. Fan furnished with power cord and polarized plug for power connection.
k. Fan brackets, finger guards and mounting hardware provided with fans to complete installation.
l. Removable Intake and Exhaust Grilles: [**ABS plastic**] [**or**] [**stainless steel**] of size to match fan size and suitable for NEMA 250, Types 1 and 12 enclosures.
m. Filters for NEMA 250, Type 1 Enclosures: Washable [**foam**] [**or**] [**aluminum**], of a size to match intake grille.
n. Filters for NEMA 250, Type 12 Enclosures: Disposable, of a size to match intake grille.

3. Air Conditioner:

a. Electric-powered, self-contained air-conditioning unit specially designed for electrical enclosures to maintain temperature inside enclosure below ambient temperature outside enclosure.
b. Thermostatic control with adjustable set point from 60 to 120 deg F.
c. Enclosure side or top mounting with unit capacity as required by application.
d. Designed for closed-loop cooling with continuous operation in ambient environments up to 125 deg F.
e. HFC refrigerant.
f. Reusable and washable air filter.
g. High-performance, industrial-grade, and high-efficiency fans.
h. Furnished with power cord and polarized plug for power connection.
i. Condensate management system with base pan side drain.
j. Mounting hardware, gaskets, mounting template and instruction manual furnished with unit.

k. Outdoor units equipped with head pressure control for low ambient operation, compressor heater, coated condenser coil and thermostat.

4. Thermoelectric Humidifier:

a. ABS plastic enclosure.
b. Capacity of 8 oz. of water per 24 hours.
c. Built-in drain captures moisture and plastic hose directs moisture to outside enclosure through a drain.
d. Controlled to maintain enclosure relative humidity at an adjustable set point.
e. Unit power supply shall be internally wired to enclosure electrical power source.

5. Framed Fixed Window Kit for NEMA 250, Types 4, 4X, and 12 Enclosures:

a. 0.25-inch-thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
b. Enclosure types, except NEMA 250 Type 1, shall have a continuous gasket material around perimeter of window and frame to provide watertight seal.
c. Window kit shall be factory or shop installed before shipment to Project.

6. Frameless Fixed Window Kit for NEMA 250, Type 1 Enclosures:

a. 0.125-inch-thick, polycarbonate window mounted in enclosure door material.
b. Window attached to door with screw fasteners and continuous strip of high-strength double-sided tape around window perimeter.
c. Window kit shall be factory or shop installed before shipment to Project.

7. Frame Fixed or Hinged Window Kit for NEMA 250, Types 1 and 12 Enclosures:

a. 0.25-inch-thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
b. Enclosure types, except NEMA 250 Type 1, shall have a continuous gasket material around perimeter of window and frame to provide watertight seal.
c. Window kit shall be factory or shop installed before shipment to Project.

8. Bar handle with keyed cylinder lock set.

2.29 RELAYS

A. General-Purpose Relays:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Relays shall be heavy duty and rated for at least 10 A at 250-V ac and 60 Hz.
3. Relays shall be either double pole double throw (DPDT) or three-pole double throw, depending on the control application.
4. Use a plug-in-style relay with an eight-pin octal plug for DPDT relays and an 11-pin octal plug for three-pole double-throw relays.
5. Construct the contacts of either silver cadmium oxide or gold.
6. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
7. Relays shall have LED indication and a manual reset and push-to-test button.

8. Performance:

   a. Mechanical Life: At least 10 million cycles.
   b. Electrical Life: At least 100,000 cycles at rated load.
   c. Pickup Time: 15 ms or less.
   d. Dropout Time: 10 ms or less.
   e. Pull-in Voltage: 85 percent of rated voltage.
   f. Dropout Voltage: 50 percent of nominal rated voltage.
   g. Power Consumption: 2 VA.
   h. Ambient Operating Temperatures: Minus 40 to 115 deg F.

9. Equip relays with coil transient suppression to limit transients to non-damaging levels.
10. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
11. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

B. Multifunction Time-Delay Relays:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Relays shall be continuous duty and rated for at least 10 A at 240-V ac and 60 Hz.
3. Relays shall be DPDT relay with up to eight programmable functions to provide on/off delay, interval and recycle timing functions.
4. Use a plug-in-style relay with either an 8- or 11-pin octal plug.
5. Construct the contacts of either silver cadmium oxide or gold.
6. Enclose the relay in a dust-tight cover.
7. Include knob and dial scale for setting delay time.
8. Performance:

   a. Mechanical Life: At least 10 million cycles.
   b. Electrical Life: At least 100,000 cycles at rated load.
   c. Timing Ranges: Multiple ranges from 0.1 seconds to 100 minutes.
   d. Repeatability: Within 2 percent.
   e. Recycle Time: 45 ms.
   f. Minimum Pulse Width Control: 50 ms.
   g. Power Consumption: 5 VA or less at 120-V ac.
   h. Ambient Operating Temperatures: Minus 40 to 115 deg F.

9. Equip relays with coil transient suppression to limit transients to non-damaging levels.
10. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
11. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

C. Latching Relays:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Relays shall be continuous duty and rated for at least 10 A at 250-V ac and 60 Hz.
3. Relays shall be either DPDT or three-pole double throw, depending on the control application.
4. Use a plug-in-style relay with a multibladed plug.

5. Construct the contacts of either silver cadmium oxide or gold.
6. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
7. Performance:

    a. Mechanical Life: At least 10 million cycles.
    b. Electrical Life: At least 100,000 cycles at rated load.
    c. Pickup Time: 15 ms or less.
    d. Dropout Time: 10 ms or less.
    e. Pull-in Voltage: 85 percent of rated voltage.
    f. Dropout Voltage: 50 percent of nominal rated voltage.
    g. Power Consumption: 2 VA.
    h. Ambient Operating Temperatures: Minus 40 to 115 deg F.

8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

D. Current Sensing Relay:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Monitors ac current.
3. Independent adjustable controls for pickup and dropout current.
4. Energized when supply voltage is present and current is above pickup setting.
5. De-energizes when monitored current is below dropout current.
6. Dropout current is adjustable from 50 to 95 percent of pickup current.
7. Include a current transformer, if required for application.
8. House current sensing relay and current transformer in its own enclosure. Use NEMA 250, Type 12 enclosure for indoors and NEMA 250, Type 4 for outdoors.

E. Combination On-Off Status Sensor and On-Off Relay:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description:

    a. On-off control and status indication in a single device.
    b. LED status indication of activated relay and current trigger.
    c. Closed-Open-Auto override switch located on the load side of the relay.

3. Performance:

    a. Ambient Temperature: Minus 30 to 140 deg F.
    b. Voltage Rating: Single-phase loads rated for 300-V ac. Three-phase loads rated for 600-V ac.

4. Status Indication:

    a. Current Sensor: Integral sensing for single-phase loads up to 20 A and external solid or split sensing ring for three-phase loads up to 150 A.
    b. Current Sensor Range: As required by application.

c. Current Set Point: [**Fixed**] [**Adjustable**] [**Fixed or adjustable as required by application**].
d. Current Sensor Output:

Retain any of first four subparagraphs below as applicable to Project.

1) Solid-state, single-pole double-throw contact rated for 30-V ac and dc and for 0.4 A.
2) Solid-state, single-pole double-throw contact rated for 120-V ac and 1.0 A.
3) Analog, zero- to 5- or 10-V dc.
4) Analog, 4 to 20 mA, loop powered.

5. Relay: Single-pole double-throw, continuous-duty coil; rated for 10-million mechanical cycles.
6. Enclosure: NEMA 250, Type 1 enclosure.

2.30 ELECTRICAL POWER DEVICES

A. Transformers:

1. Transformer shall be sized for the total connected load, plus an additional 25 percent of connected load.
2. Transformer shall be at least [**40**] [**100**] <**Insert value**> VA.
3. Transformer shall have both primary and secondary fuses.

B. Power-Line Conditioner:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. General Power-Line Conditioner Requirements:

a. Design to ensure maximum reliability, serviceability and performance.
b. Overall function of the power-line conditioner is to receive raw, polluted electrical power and purify it for use by electronic equipment. The power-line conditioner shall provide isolated, regulated, transient and noise-free sinusoidal power to loads served.

3. Standards: NRTL listed per UL 1012.
4. Performance:

a. Single phase, continuous, 100 percent duty rated KVA/KW capacity. Design to supply power for linear or nonlinear, high crest factor, resistive and reactive loads.
b. Automatically regulate output voltage to within 2 percent or better with input voltage fluctuations of plus 10 to minus 20 percent of nominal when system is loaded 100 percent. Use Variable Range Regulation to obtain improved line voltage regulation when operating under less than full load conditions.

1) At 75 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 35 percent of nominal.

2) At 50 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 40 percent of nominal.
3) At 25 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 45 percent of nominal.

c. With input voltage distortion of up to 40 percent, limit the output voltage sine wave to a maximum harmonic content of 5 percent.
d. Automatically regulate output voltage to within 2.5 percent when load (resistive) changes from zero percent to 100 percent to zero percent.
e. Output voltage returns to 95 percent of nominal level within two cycles and to 100 percent within three cycles when the output is taken from no load to full resistive load or vice-versa. Recovery from partial resistive load changes is corrected in a shorter period of time.
f. K Factor: 30, designed to operate with nonlinear, non-sinusoidal, high crest factor loads without overheating.
g. Input power factor within 0.95 approaching unity with load power factor as poor as 0.6.
h. Attenuate load-generated odd current harmonics 23 dB at the input.
i. Electrically isolate the primary from the secondary. Meet isolation criteria as defined in NFPA 70, Article 250-5D.
j. Lighting and Surge Protection: Compares to UL 1449 rating of 330 V when subjected to Category B3 (6000 V/3000 A) combination waveform as established by IEEE C62.41.
k. Common-mode noise attenuation of 140 dB.
l. Transverse-mode noise attenuation of 120 dB.
m. With loss of input power for up to 16.6 ms, the output sine wave remains at usable ac voltage levels.
n. Reliability of 200,000 hours' MTBF.
o. At full load, when measured at 1-m distance, audible noise is not to exceed 54 dB.
p. Approximately 92 percent efficient at full load.

5. Transformer Construction:

a. Ferroresonant, dry type, convection cooled, 600V class. Transformer windings of Class H (220 deg C) insulated copper.
b. Use a Class H installation system throughout with operating temperatures not to exceed 150 deg C over a 40-deg C ambient temperature.
c. Configure transformer primary for multi-input voltage. Include input terminals for source conductors and ground.
d. Manufacture transformer core using M-6 grade, grain-oriented, stress-relieved transformer steel.
e. Configure transformer secondary in a 240/120-V split with a 208-V tap or straight 120 V, depending on power output size.
f. Electrically isolate the transformer secondary windings from the primary windings. Bond neutral conductor to cabinet enclosure and output neutral terminal.
g. Include interface terminals for output power hot, neutral and ground conductors.
h. Label leads, wires and terminals to correspond with circuit wiring diagram.
i. Vacuum impregnate transformer with epoxy resin.

6. Cabinet Construction:

    a. Design for panel or floor mounting.
    b. NEMA 250, Type 1, general-purpose, indoor enclosure.
    c. Manufacture the cabinet from heavy gauge steel complying with UL 50.
    d. Include a textured baked-on paint finish.

C. Transient Voltage Suppression and High-Frequency Noise Filter Unit:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. The maximum continuous operating voltage shall be at least 125 percent.
3. The operating frequency range shall be 47 to 63 Hz.
4. Protection modes according to NEMA LS-1.
5. The rated single-pulse surge current capacity, for each mode of protection, shall be no less than the following:

    a. Line to Neutral: 45,000 A.
    b. Neutral to Ground: 45,000 A.
    c. Line to Ground: 45,000 A.
    d. Per Phase: 90,000 A.

6. Clamping voltages shall be in compliance with test and evaluation procedures defined in NEMA LS-1. Maximum clamping voltage shall be as follows:

    a. Line to Neutral: 360 V.
    b. Line to Ground: 360 V.
    c. Neutral to Ground: 360 V.

7. Electromagnetic interference and RF interference noise rejection or attenuation values shall comply with test and evaluation procedures defined in NEMA LS-1.

    a. Line to Neutral:

        1) 100 kHz: 42 dB.
        2) 1 MHz: 25 dB.
        3) 10 MHz: 21 dB.
        4) 100 MHz: 36 dB.

    b. Line to Ground:

        1) 100 kHz: 16 dB.
        2) 1 MHz: 55 dB.
        3) 10 MHz: 81 dB.
        4) 100 MHz: 80 dB.

8. Unit shall have LED status indicator that extinguishes to indicate a failure.
9. Unit shall be listed by an NRTL as a transient voltage surge suppressor per UL 1449, and as an electromagnetic interference filter per UL 1283.
10. Unit shall not generate any appreciable magnetic field.
11. Unit shall not generate an audible noise.

D. DC Power Supply:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Plug-in style suitable for mating with a standard eight-pin octal socket. Include the power supply with a mating mounting socket.
3. Enclose circuitry in a housing.
4. Include both line and load regulation to ensure a stable output. To protect both the power supply and the load, power supply shall have an automatic current limiting circuit.
5. Performance:

    a. Output voltage nominally 25-V dc within 5 percent.
    b. Output current up to 100 mA.
    c. Input voltage nominally 120-V ac, 60 Hz.
    d. Load regulation within 0.5 percent from zero- to 100-mA load.
    e. Line regulation within 0.5 percent at a 100-mA load for a 10 percent line change.
    f. Stability within 0.1 percent of rated volts for 24 hours after a 20-minute warmup.

2.31 UNINTERRUPTABLE POWER SUPPLY (UPS) UNITS FOR WORKSTATIONS

A. 250 through 1000 VA:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. UPS units shall provide continuous, regulated output power without using their batteries during brown-out, surge, and spike conditions.
3. Load served shall not exceed 75 percent of UPS rated capacity, including power factor of connected loads.

    a. Larger-capacity units shall be provided for systems with larger connected loads.
    b. UPS shall provide [**five**] <**Insert number**> minutes of battery power.

4. Performance:

    a. Input Voltage: Single phase, 120- or 230-V ac, compatible with field power source.
    b. Load Power Factor Range (Crest Factor): 0.65 to 1.0.
    c. Output Voltage: 101- to 132-V ac, while input voltage varies between 89 and 152-V ac.
    d. On Battery Output Voltage: Sine wave.
    e. Inverter overload capacity shall be minimum 150 percent for 30 seconds.
    f. Recharge time shall be a maximum of six hours to 90 percent capacity after full discharge to cutoff.
    g. Transfer Time: 6 ms.
    h. Surge Voltage Withstand Capacity: IEEE C62.41, Categories A and B; 6 kV/200 and 500 A; 100-kHz ringwave.

5. UPS shall be automatic during fault or overload conditions.
6. Unit with integral line-interactive, power condition topology to eliminate all power contaminants.
7. Include front panel with power switch and visual indication of power, battery, fault and temperature.

8. Unit shall include an audible alarm of faults and front panel silence feature.
9. Unit with four NEMA WD 1, NEMA WD 6 Configuration 5-15R receptacles.
10. UPS shall include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure)[**and connect the points to the DDC system**].
11. Batteries shall be sealed lead-acid type and be maintenance free. Battery replacement shall be front accessible by user without dropping load.
12. Include tower models installed in ventilated cabinets to the particular installation location.

B. 1000 through 3000 VA:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. UPS units shall provide continuous, regulated output power without using their batteries during brown-out, surge, and spike conditions.
3. Load served shall not exceed 75 percent of UPS rated capacity, including power factor of connected loads.

   a. Larger-capacity units, or multiple units, shall be provided for systems with larger connected loads.
   b. UPS shall provide [**five**] [**10**] <**Insert number**> minutes of battery power.

4. Performance:

   a. Input Voltage: Single phase, 120-V ac, plus 20 to minus 30 percent.
   b. Power Factor: Minimum 0.97 at full load.
   c. Output Voltage: Single phase, 120-V ac, within 3 percent, steady state with rated output current of 10.0 A, 30.0-A peak.
   d. Inverter overload capacity shall be minimum 150 percent for 30 seconds.
   e. Recharge time shall be a maximum of eight hours to 90 percent capacity.

5. UPS bypass shall be automatic during fault or overload conditions.
6. UPS shall include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure)[**and connect the points to the DDC system**].
7. Batteries shall be sealed lead-acid type and be maintenance free.
8. Include tower models installed in ventilated cabinets or rack models installed on matching racks, as applicable to the particular installation location and space availability/configuration.

2.32 PIPING AND TUBING

A. Pneumatic, and Pressure Instrument Signal Air, Tubing and Piping:

1. Products in this paragraph are intended for use with the following:

Retain first subparagraph below if Project includes pneumatic products.

   a. Main air and signal air to pneumatically controlled instruments, actuators and other control devices and accessories.
   b. Signal air between pressure instruments, such as sensors, switches, transmitters, controllers and accessories.

2. Copper Tubing:

   a. Seamless phosphor deoxidized copper, soft annealed or drawn tempered, with chemical and physical properties according to ASTM B75.
   b. Performance, dimensions, weight and tolerance according to ASTM B280.
   c. Diameter, as required by application, not less than nominal 0.25 inch.
   d. Wall thickness, as required by the application, but not less than 0.030 inch.

3. Copper Tubing Connectors and Fittings:

   a. Brass, compression type.

      1) <Double click here to find, evaluate, and insert list of manufacturers and products.>

   b. Brass, solder-joint type.

      1) <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain "Galvanized-Steel Piping" Subparagraph if required by Project. Galvanized-steel pipe is not typically used on most projects.

4. Galvanized-Steel Piping:

   a. Galvanized pipe shall be ASTM A53/A53M, Schedule 40.
   b. Fittings, galvanized malleable iron, ASME B16.3, Class 150.

5. Polyethylene Tubing:

   a. Fire-resistant black virgin polyethylene according to ASTM D1248, Type 1, Class C and Grade 5.
   b. Tubing shall comply with stress crack test according to ASTM D1693.
   c. Diameter, as required by application, of not less than nominal 0.25 inch.

6. Polyethylene Tubing Connectors and Fittings:

   a. Brass, barbered fittings.

      1) <Double click here to find, evaluate, and insert list of manufacturers and products.>

   b. Brass, compression type.

      1) <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Process Tubing:

1. Products in this paragraph are intended for signals to instruments connected to liquid and steam systems.

Retain one of or both "Copper Tubing" and "Stainless-Steel Tubing" subparagraphs below as applicable to Project.

2. Copper Tubing:

   a. Seamless phosphor deoxidized copper, soft annealed or drawn tempered with chemical and physical properties according to ASTM B75.
   b. Performance, dimensions, weight and tolerance according to ASTM B280.
   c. Diameter, as required by application, of not less than nominal 0.25 inch.
   d. Wall thickness, as required by application, but not less than 0.030 inch.

3. Copper Tubing Connectors and Fittings:

   a. Brass, compression type.

      1) <Double click here to find, evaluate, and insert list of manufacturers and products.>

   b. Brass, solder-joint type.

      1) <Double click here to find, evaluate, and insert list of manufacturers and products.>

4. Stainless-Steel Tubing:

   a. Seamless Type 316 stainless steel, Grade TP, cold drawn, annealed and pickled, free from scale.
   b. Chemical and physical properties according to ASTM A269.
   c. Diameter, as required by application, of not less than nominal 0.25 inch.
   d. Wall thickness, as required by application, but not less than 0.035 inch.
   e. Furnish stainless-steel tubing in [**20-foot**] straight random lengths.

5. Stainless-Steel Tubing Connectors and Fittings:

   a. Connectors and fittings shall be stainless steel, with stainless-steel collets, flareless type.

      1) <Double click here to find, evaluate, and insert list of manufacturers and products.>

   b. Connect instruments to tubing with connectors having compression connector on one end and IPS or NPT thread on other end.

2.33 CONTROL WIRE AND CABLE

A. Wire: Single conductor control wiring above 24 V.

1. Wire size shall be at least [**No. 18**] [**No. 16**] [**No. 14**] <**Insert value**> AWG.
2. Conductor shall be 7/24 soft annealed copper strand with 2- to 2.5-inch lay.
3. Conductor insulation shall be 600 V, Type THWN or Type THHN, and 90 deg C according to UL 83.
4. Conductor colors shall be black (hot), white (neutral), and green (ground).

5. Furnish wire on spools.

B. Single Twisted Shielded Instrumentation Cable above 24 V:

1. Wire size shall be a minimum [**No. 18**] [**No. 20**] [**No. 22**] <**Insert value**> AWG.
2. Conductors shall be a twisted, 7/24 soft annealed copper strand with a 2- to 2.5-inch lay.
3. Conductor insulation shall have a Type THHN/THWN or Type TFN rating.
4. Shielding shall be 100 percent type, 0.35/0.5-mil aluminum/Mylar tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
5. Outer jacket insulation shall have a 600-V, 90-deg C rating and shall be Type TC cable.
6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red and white.
7. Furnish wire on spools.

C. Single Twisted Shielded Instrumentation Cable 24 V and Less:

1. Wire size shall be a minimum [**No. 18**] [**No. 20**] [**No. 22**] <**Insert value**> AWG.
2. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2.5-inch lay.
3. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
4. Shielding shall be 100 percent type, 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
5. Outer jacket insulation shall have a 300-V, 105-deg C rating and shall be Type PLTC cable.
6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red and white.
7. Furnish wire on spools.

D. LAN and Communication Cable: Comply with DDC system manufacturer requirements for network being installed.

1. Cable shall be balanced twisted pair.
2. Comply with the following requirements and for balanced twisted pair cable described in [**Section 260523 "Control-Voltage Electrical Power Cables."**] [**Section 271513 "Communications Copper Horizontal Cabling."**]

   a. Cable shall be plenum rated.
   b. Cable shall have a unique color that is different from other cables used on Project.

2.34 RACEWAYS

A. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.

B. Comply with requirements in Section 270528 "Pathways for Communications Systems" for raceways for balanced twisted pair cables and optical fiber cables.

2.35 OPTICAL FIBER CABLE AND CONNECTORS

A. Comply with requirements in Section 271323 "Communications Optical Fiber Backbone Cabling" for optical fiber backbone cabling and connectors.

B. Comply with requirements in Section 271523 "Communications Optical Fiber Horizontal Cabling" for optical fiber horizontal cabling and connectors.

2.36 ACCESSORIES

A. Pneumatic Pressure Gages:

1. Pressure gages shall a 1.5-inch-diameter face for pressures up through 30 psig and 2.5-inch-diameter face for greater pressures.
2. Include separate gages for branch pressure and main pressure lines.
3. White dial face with black printing.
4. Include 1-psig increment for scale ranges through 30 psig and 2-psig increment for larger ranges.
5. Accuracy: Within 1 percent of full-scale range.

B. Pressure Electric Switches:

1. Diaphragm-operated snap acting switch.
2. Set point adjustable from 3 to 20 psig.
3. Differential adjustable from 2 to 6 psig.
4. Rated for resistance loads at 120-V ac.
5. Body and switch housing shall be metal.

C. Damper Blade Limit Switches:

1. Sense positive open and/or closed position of the damper blades.
2. NEMA 250, Type 13, oil-tight construction.
3. Arrange for the mounting application.
4. Additional waterproof enclosure when required by its environment.
5. Arrange to prevent "over-center" operation.

D. I/P and E/P Transducers:

1. Commercial Grade:

   a. <Double click here to find, evaluate, and insert list of manufacturers and products.>
   b. The transducer shall convert an AO signal to a stepped pneumatic signal. Unless otherwise required by the operating sequence, use a 3- to 15-psig pneumatic signal for pneumatic actuation.
   c. Construct the entire assembly so that shock and vibration will neither harm the transducer nor affect its accuracy.
   d. Transducer shall have auto/manual output switch, manual output control and an output pressure gage.
   e. Accuracy: Within 1.0 percent of the output span.

f. Linearity: Within 0.5 percent of the output span.
g. Output Capacity: Not less than 550 scim at 15 psig.
h. Transducer shall have separate zero and span calibration adjustments.
i. The transducer shall withstand up to 40 psig of supply pressure without damage.
j. For use on only modulating pneumatic outputs that are associated with terminal units, including fan-coil units, VAV units, unit heaters and <**Insert equipment**>.

2. Industrial Grade:

a. <Double click here to find, evaluate, and insert list of manufacturers and products.>
b. The transducer shall convert an AO signal to a proportional pneumatic signal. Unless otherwise required by the operating sequence, use a 3- to 15-psig pneumatic signal for pneumatic actuation. A stepped pneumatic signal is unacceptable.
c. Construct the entire assembly so that shock and vibration will neither harm the transducer nor affect its accuracy.
d. Suitable for operation in an ambient temperature range of minus 40 to 150 deg F.
e. Accuracy: Within 0.5 percent of the output span.
f. Linearity: Within 0.5 percent of the output span.
g. Output Capacity: Not less than 5 scfm.
h. Transducer shall have zero and span calibration adjustments.
i. The transducer shall withstand up to 50 psig of supply pressure without damage.
j. For use on all modulating pneumatic outputs, not requiring a commercial-grade transducer.

E. E/P Switch:

1. Construct the body of cast aluminum or brass; three pipe body (common, normally open, and normally closed).
2. Internal construction of steel, copper or brass.
3. Air Connections: Barb.
4. Rating of 30 psig when installed in systems below 25 psig and of 150 psig when installed in systems above 25 psig.
5. Include coil transient suppression.

F. Instrument Enclosures:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Include instrument enclosure for secondary protection to comply with requirements indicated in "Performance Requirements" Article.
3. NRTL listed and labeled to UL 50.
4. Sized to include at least 25 percent spare area on subpanel.
5. Instrument(s) mounted within enclosure on internal subpanel(s).
6. Enclosure face with engraved, laminated phenolic nameplate for each instrument within enclosure.
7. Enclosures housing pneumatic instruments shall include main pressure gage and a branch pressure gage for each pneumatic device, installed inside.
8. Enclosures housing multiple instruments shall route tubing and wiring within enclosure in a raceway having a continuous removable cover.

9. Enclosures larger than [**12 inches**] <**Insert dimension**> shall have a hinged full-size face cover.

Retain subparagraph below for applications requiring additional security.

10. Equip enclosure with lock and common key.

G. Manual Valves:

1. Needle Type:

a. <Double click here to find, evaluate, and insert list of manufacturers and products.>
b. PTFE packing.
c. Construct of brass for use with copper and polyethylene tubing and of stainless steel for use with stainless-steel tubing.
d. Aluminum T-bar handle.
e. Include tubing connections.

2. Ball Type:

a. <Double click here to find, evaluate, and insert list of manufacturers and products.>
b. Body: Bronze ASTM B62 or ASTM B61.
c. Ball: Type 316 stainless steel.
d. Stem: Type 316 stainless steel.
e. Seats: Reinforced PTFE.
f. Packing Ring: Reinforced PTFE.
g. Lever: Stainless steel with a vinyl grip.
h. 600 WOG.
i. Threaded end connections.

H. Wall-Mounted Portable Workstation Cabinet:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Surface-mounted wall cabinet for tilt-out operation of laptop computers and large-format mobile devices.
3. Cabinet shall have a load limit of 50 lb.
4. Cabinet shall include the following:

a. Oil-filled dampers for controlled lowering of equipment to operational position.
b. 3RU EIA mounting rails.
c. Removable laptop shelf.
d. Separate top compartment with mounting area, hinged rail and security lock.
e. Front ventilation slots.
f. Knockouts for conduit connections on top and bottom of cabinet.

5. Cabinet shall be constructed of steel and painted with a powder-coat epoxy.
6. Inside center of backbox shall have provision to mount a field-furnished and -installed, single gang electrical outlet box.

2.37 IDENTIFICATION

A. Instrument Air Pipe and Tubing:

1. Engraved tag shall bear the following information:

a. Service (Example): "Instrument Air."
b. Pressure Range (Example): 0 to 30 psig.

2. Letter size shall be a minimum of [**0.25 inch**] <**Insert dimension**> high.
3. Tag shall consist of white lettering on blue background.
4. Tag shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded blue with contrasting white center exposed by engraving through outer layer.
5. Include tag with a brass grommet, chain and S-hook.

B. Control Equipment, Instruments, and Control Devices:

1. [**Self-adhesive label**] [**Laminated acrylic or melamine plastic sign**] bearing unique identification.

a. Include instruments with unique identification identified by equipment being controlled or monitored, followed by point identification.

2. Letter size shall be as follows:

First 12 subparagraphs below are examples only.

a. Operator Workstations: Minimum of [**0.5 inch**] <**Insert dimension**> high.
b. Servers: Minimum of [**0.5 inch**] <**Insert dimension**> high.
c. Printers: Minimum of [**0.5 inch**] <**Insert dimension**> high.
d. DDC Controllers: Minimum of [**0.5 inch**] <**Insert dimension**> high.
e. Gateways: Minimum of [**0.5 inch**] <**Insert dimension**> high.
f. Repeaters: Minimum of [**0.5 inch**] <**Insert dimension**> high.
g. Enclosures: Minimum of [**0.5 inch**] <**Insert dimension**> high.
h. Electrical Power Devices: Minimum of [**0.25 inch**] <**Insert dimension**> high.
i. UPS units: Minimum of [**0.5 inch**] <**Insert dimension**> high.
j. Accessories: Minimum of [**0.25 inch**] <**Insert dimension**> high.
k. Instruments: Minimum of [**0.25 inch**] <**Insert dimension**> high.
l. Control Damper and Valve Actuators: Minimum of [**0.25 inch**] <**Insert dimension**> high.

3. Legend shall consist of white lettering on black background.
4. Laminated acrylic or melamine plastic sign shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded black with contrasting white center exposed by engraving through outer layer and shall be fastened with drive pins.
5. Instruments, control devices and actuators with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require additional identification.

C. Valve Tags:

1. Brass tags and brass chains attached to valve.
2. Tags shall be at least [**1.5 inches**] <**Insert dimension**> in diameter.
3. Include tag with unique valve identification indicating control influence such as flow, level, pressure, or temperature; followed by location of valve, and followed by three-digit sequential number. For example: TV-1.001.
4. Valves with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.

D. Raceway and Boxes:

1. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
2. Paint cover plates on junction boxes and conduit same color as the tape banding for conduits. After painting, label cover plate "HVAC Controls," using an engraved phenolic tag.

Retain first subparagraph below if Project includes pneumatic products.

3. For raceways housing pneumatic tubing, add a phenolic tag labeled "HVAC Instrument Air Tubing."
4. For raceways housing air signal tubing, add a phenolic tag labeled "HVAC Air Signal Tubing."

E. Equipment Warning Labels:

1. Self-adhesive label with pressure-sensitive adhesive back and peel-off protective jacket.
2. Lettering size shall be at least 14-point type with white lettering on red background.
3. Warning label shall read "CAUTION-Equipment operated under remote automatic control and may start or stop at any time without warning. Switch electric power disconnecting means to OFF position before servicing."
4. Lettering shall be enclosed in a white line border. Edge of label shall extend at least [**0.25 inch**] <**Insert dimension**>beyond white border.

2.38 SOURCE QUALITY CONTROL

This article covers tests and inspections performed at the source to verify that products and materials comply with requirements specified.

Retain "Testing Agency" Paragraph below if retaining "DDC System Reliability" Paragraph in "Performance Requirements" Article and to require independent evaluation. Independent evaluation may be required whether "DDC System Reliability" is required. Independent certification may be acceptable to authorities having jurisdiction without further monitoring of plant's quality-control and testing program by Owner.

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to evaluate the following according to industry standards for each product, and to verify DDC system reliability specified in performance requirements:

1. DDC controllers.
2. Gateways.
3. Routers.
4. Operator workstations.
5. <**Insert product**>.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

B. Product(s) [**and**] [**material(s)**] will be considered defective if [**it does**] [**they do**] not pass tests and inspections.

C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

1. Verify compatibility with and suitability of substrates.

B. Examine roughing-in for products to verify actual locations of connections before installation.

1. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
2. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.

C. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.

D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

Retain "Communication Interface to Equipment with Integral Controls" Paragraph below to require DDC system to monitor or control equipment through a communication link.

A. Communication Interface to Equipment with Integral Controls:

1. DDC system shall have communication interface with equipment having integral controls and having a communication interface for remote monitoring or control.

Retain "Equipment to Be Connected" Subparagraph below to require equipment to be connected to DDC system through a communication interface; delete if equipment to be connected is indicated on Drawings. Coordinate with Drawings.

2. Equipment to Be Connected:

Retain applicable subparagraphs below. Coordinate specific interface requirements in Sections specifying equipment.

a. Domestic water booster pumps specified in Section 221123.13 "Domestic-Water Packaged Booster Pumps."
b. Air-terminal units specified in Section 233600 "Air Terminal Units."
c. Kitchen hoods specified in Section 233813 "Commercial-Kitchen Hoods."
d. Boilers specified in Section 235213 "Electric Boilers."
e. Boilers specified in Section 235216 "Condensing Boilers."
f. Boilers specified in Section 235223 "Cast-Iron Boilers."
g. Boilers specified in Section 235233 "Water-Tube Boilers."
h. Boilers specified in Section 235239 "Fire-Tube Boilers."
i. Feedwater equipment specified in Section 235313 "Boiler Feedwater Pumps."
j. Deaerators specified in Section 235316 "Deaerators."
k. Chillers specified in Section 236413.13 "Direct-Fired Absorption Water Chillers."
l. Chillers specified in Section 236413.16 "Indirect-Fired Absorption Water Chillers."
m. Chillers specified in Section 236416 "Centrifugal Water Chillers."
n. Chillers specified in Section 236423.13 "Air-Cooled, Scroll Water Chillers."
o. Chillers specified in Section 236423.16 "Water-Cooled, Scroll Water Chillers."
p. Chillers specified in Section 236426.13 "Air-Cooled, Rotary-Screw Water Chillers."
q. Chillers specified in Section 236426.16 "Water-Cooled, Rotary-Screw Water Chillers."
r. Cooling towers specified in Section 236513.13 "Open-Circuit, Forced-Draft Cooling Towers."
s. Cooling towers specified in Section 236513.16 "Closed-Circuit, Forced-Draft Cooling Towers."
t. Cooling towers specified in Section 236514.13 "Open-Circuit, Induced-Draft, Counterflow Cooling Towers."
u. Cooling towers specified in Section 236514.14 "Open-Circuit, Induced-Draft, Crossflow Cooling Towers."
v. Cooling towers specified in Section 236514.16 "Closed-Circuit, Induced-Draft, Counterflow Cooling Towers."
w. Cooling towers specified in Section 236514.17 "Closed-Circuit, Induced-Draft, Combined-Flow Cooling Towers."
x. Heat wheels and heat exchangers specified in Section 237223 "Air-to-Air Energy Recovery Equipment."
y. Air-handling units specified in Section 237313 "Modular Indoor Central-Station Air-Handling Units."
z. Roof-top units specified in Section 237413 "Packaged, Outdoor, Central-Station Air-Handling Units."
aa. Dedicated outdoor-air units specified in Section 237433 "Dedicated Outdoor-Air Units."
bb. Packaged terminal air-conditioners specified in Section 238113.11 "Packaged Terminal Air-Conditioners, Through-Wall Units."

cc. Packaged terminal air-conditioners specified in Section 238113.12 "Packaged Terminal Air-Conditioners, Freestanding Units."
dd. Packaged terminal air-conditioners specified in Section 238113.13 "Packaged Terminal Air-Conditioners, Outdoor, Wall-Mounted Units."
ee. Computer-room air-conditioning units specified in Section 238123.11 "Small-Capacity (6 Tons (21 kW) and Smaller), Computer-Room Air-Conditioners, Floor Mounted Units."
ff. Computer-room air-conditioning units specified in Section 238123.12 "Large-Capacity (7 Tons (25 kW) and Larger), Computer-Room Air-Conditioners, Floor Mounted Units."
gg. Computer-room air-conditioning units specified in Section 238123.13 "Computer-Room Air Conditioners, Ceiling-Mounted Units."
hh. Computer-room air-conditioning units specified in Section 238123.14 "Computer-Room Air Conditioners, Console Units."
ii. Computer-room, rack-mounted cooling equipment specified in Section 238123.18 "Computer-Room, Rack-Cooling Equipment."
jj. Fan-coil units specified in Section 238219 "Fan Coil Units."
kk. Unit ventilators specified in Section 238223 "Unit Ventilators."
ll. Wetted-element humidifiers specified in Section 238413.16 "Wetted-Element Humidifiers."
mm. Atomizing humidifiers specified in Section 238413.19 "Atomizing Humidifiers."
nn. Direct-steam-injection humidifiers specified in Section 238413.23 "Direct-Steam-Injection Humidifiers."
oo. Self-contained steam humidifiers specified in Section 238413.29 "Self-Contained Steam Humidifiers."
pp. Heat exchanger humidifiers specified in Section 238413.36 "Heat Exchanger Humidifiers."
qq. Dehumidification units specified in Section 238416 "Mechanical Dehumidification Units."
rr. Switchboards specified in Section 262300 "Low-Voltage Switchgear."
ss. Motor-control centers specified in Section 262419 "Motor-Control Centers."
tt. Variable-frequency controllers specified in Section 262923 "Variable-Frequency Motor Controllers."
uu. Diesel emergency engine generators specified in Section 263213.13 "Diesel Emergency Engine Generators."
vv. Diesel engine generators specified in Section 263213.14 "Diesel Engine Generators."
ww. Gaseous emergency engine generators specified in Section 263213.16 "Gaseous Emergency Engine Generators."
xx. Gaseous engine generators specified in Section 263213.17 "Gaseous Engine Generators."
yy. Bi-fuel emergency engine generators specified in Section 263213.19 "Bi-Fuel Emergency Engine Generators."
zz. Bi-fuel engine generators specified in Section 263213.20 "Bi-Fuel Engine Generators."
aaa. UPS specified in Section 263353 "Static Uninterruptible Power Supply."
bbb. Refrigerant monitoring.
ccc. <**Insert equipment and Section number and title**>.

Retain "Communication Interface to Other Building Systems" Paragraph below to require DDC system to interface with systems through a communication link.

B. Communication Interface to Other Building Systems:

1. DDC system shall have a communication interface with systems having a communication interface.

Retain "Systems to Be Connected" Subparagraph below to indicate systems to be connected; delete if systems to be connected are indicated on Drawings. Coordinate with Drawings.

2. Systems to Be Connected:

Coordinate specific interface requirements in the Sections retained in remaining subparagraphs below.

a. Elevators specified in Section 142100 "Electric Traction Elevators."
b. Elevators specified in Section 142113 "Electric Traction Freight Elevators."
c. Elevators specified in Section 142400 "Hydraulic Elevators."
d. Elevators specified in Section 142413 "Hydraulic Freight Elevators."
e. Escalators specified in Section 143100 "Escalators."
f. Automated water treatment systems specified in Section 232500 "HVAC Water Treatment."
g. Automated water treatment systems specified in Section 232516 "Water Treatment for Open-Loop Hydronic Systems."
h. Automated water treatment systems specified in Section 232519 "Water Treatment for Steam System Feedwater."
i. Power monitoring specified in Section 260913 "Electrical Power Monitoring and Control."
j. Lighting controls specified in Section 260926 "Lighting Control Panelboards."
k. Lighting controls specified in Section 260943.16 "Addressable-Luminaire Lighting Controls."
l. Lighting controls specified in Section 260943.23 "Relay-Based Lighting Controls."
m. Fire-alarm system specified in Section 284621.11 "Addressable Fire-Alarm Systems."
n. Fire-alarm system specified in Section 284621.13 "Conventional Fire-Alarm Systems."
o. Access controls specified in Section 281300 "Access Control System Software and Database Management."
p. Intrusion detection specified in Section 283100 "Intrusion Detection."
q. Perimeter security specified in Section 283121 "Area and Perimeter Intrusion Detection."
r. <**Insert system and Section number and title**>.

3.3 DDC SYSTEM INTERFACE WITH EXISTING SYSTEMS

Retain "Interface with Existing Systems" Paragraph below to require DDC system to be connected to existing systems. Include special instructions in Document 002213 "Supplementary Instructions to Bidders" to instruct bidders to visit Project to become familiar with systems to be connected and available interface requirements and to report findings with bids.

A. Interface with Existing Systems:

1. DDC systems shall interface existing systems to achieve integration.

Retain "Monitoring and Control of DDC System by Existing Control System" Subparagraph below when DDC system being installed is to integrate with existing system.

2. Monitoring and Control of DDC System by Existing Control System:

   a. DDC system performance requirements shall be satisfied when monitoring and controlling DDC system by existing control system.
   b. Operator of existing system shall be able to upload, download, monitor, trend, control and program every input and output point in DDC system from existing control system using existing control system software and operator workstations.
   c. Remote monitoring and control from existing control system shall not require operators of existing control system to learn new software.
   d. Interface of DDC system into existing control system shall be transparent to operators of existing control system and allow operators to [**program, monitor, and control**] [**monitor and control**] DDC system from any operator workstation connected to existing control system.
   e. <**Insert requirements**>.

Retain "Integration of Existing Control System into DDC System" Subparagraph below to require existing system to be integrated into DDC system.

3. Integration of Existing Control System into DDC System:

   a. Existing control system performance requirements shall be satisfied when monitoring and controlling existing control system through DDC system.
   b. Operator shall be able to upload, download, monitor, alarm, report, trend, control and program every input and output point in existing system from DDC system using operator workstations and software provided. The combined systems shall share one database.
   c. Interface of existing control system I/O points into DDC system shall be transparent to operators. All operational capabilities shall be identical regardless of whether I/O already exists or I/O is being installed.
   d. <**Insert requirements**>.

Retain "Integration with Existing Enterprise System" Paragraph below where required to connect to existing enterprise system.

B. Integration with Existing Enterprise System:

1. DDC system shall interface with an existing enterprise system to adhere to Owner standards already in-place and to achieve integration.

Retain one of first two subparagraphs below where required to connect to existing enterprise system that requires services of Owner's existing control system integrator.

2. Owner's control system integrator will provide the following services:

   a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
   b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.

c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.

3. Engage Owner's control system integrator to provide the following services:

a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.

4. Control System Integrator Contact Information:

a. Company: <**Insert name**>.
b. Company Street Address: <**Insert address**>.
c. Company Contact: <**Insert name**>.
d. Phone Number: <**Insert phone number**>.
e. E-mail Address: <**Insert e-mail address**>.

5. Attend meetings with control system integrator to integrate DDC system.

3.4 CONTROL DEVICES FOR INSTALLATION BY INSTALLERS

Coordinate requirements in this article with requirements in Sections specifying the identified equipment and systems. This article includes examples of requirements but is not all-inclusive. Requirements must be revised to comply with specific Project requirements.

A. Deliver selected control devices, specified in indicated HVAC instrumentation and control device Sections, to identified equipment and systems manufacturers for factory installation and to identified installers for field installation.

Both paragraphs below are examples only. Retain and revise as applicable.

B. Deliver the following to duct fabricator and Installer for installation in ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.

1. DDC control dampers, which are specified in Section 230923.12 "DDC Control Dampers."
2. Airflow sensors and switches, which are specified in Section 230923.14 "Flow Instruments."
3. Pressure sensors, which are specified in Section 230923.23 "Pressure Instruments."
4. <**Insert additional control devices**>.

C. Deliver the following to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.

1. DDC control valves, which are specified in Section 230923.11 "Control Valves."

2. Pipe-mounted flow meters, which are specified in Section 230923.14 "Flow Instruments."
3. Pipe-mounted sensors, switches and transmitters. Flow meters are specified in Section 230923.14 "Flow Instruments." Liquid[**and steam**] temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
4. Tank-mounted sensors, switches and transmitters. Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments." Liquid[**and steam**] temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
5. Pipe- and tank-mounted thermowells. Liquid[**and steam**] thermowells are specified in Section 230923.27 "Temperature Instruments."
6. <**Insert additional control devices**>.

3.5 CONTROL DEVICES FOR EQUIPMENT MANUFACTURER FACTORY INSTALLATION

Paragraphs in this article are examples only. Retain and revise as applicable.

A. Deliver the following to air-handling unit manufacturer for factory installation. Include installation instructions to air-handling unit manufacturer[**and supervise installation for compliance with requirements**].

1. [**Programmable application**] [**or**] [**application-specific**] controller.
2. Unit-mounted DDC control dampers and actuators, which are specified in Section 230923.12 "Control Dampers."
3. Unit-mounted airflow sensors, switches and transmitters, which are specified in Section 230923.14 "Flow Instruments."
4. Unit-mounted gas sensors and transmitters, which are specified in Section 230923.16 "Gas Instruments."
5. Unit-mounted leak-detection switches, which are specified in Section 230923.18 "Leak-Detection Instruments."
6. Unit-mounted speed sensors, switches and transmitters, which are specified in Section 230923.24 "DDC Speed Instruments."
7. Unit-mounted pressure sensors, switches and transmitters, which are specified in Section 230923.23 "Pressure Instruments."
8. Unit-mounted temperature sensors, switches and transmitters. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
9. Relays.
10. <**Insert additional control devices**>.

B. Deliver the following to terminal unit manufacturer for factory installation. Include installation instructions to terminal unit manufacturer.

1. [**Programmable application**] [**or**] [**application-specific**] controller.
2. Electric damper actuator. Dampers actuators are specified in Section 230923.12 "Control Dampers."
3. Unit-mounted flow and pressure sensors, transmitters and transducers. Flow sensors, transmitters, and transducers are specified in Section 230923.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."

4. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
5. Relays.
6. <**Insert additional control devices**>.

C. Deliver the following to fan-coil unit manufacturer for factory installation. Include installation instructions to fan-coil unit manufacturer.

1. [**Programmable application**] [**or**] [**application-specific**] controller.
2. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
3. Flow and pressure switches. Air and liquid flow sensors, transmitters, and transducers are specified in Section 230923.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."
4. Leak-detection switches, which are specified in Section 230923.18 "Leak-Detection Instruments."
5. Relays.
6. <**Insert additional control devices**>.

3.6 GENERAL INSTALLATION REQUIREMENTS

A. Install products to satisfy more stringent of all requirements indicated.

B. Install products level, plumb, parallel, and perpendicular with building construction.

C. Support products, tubing, piping wiring and raceways. Brace products to prevent lateral movement and sway or a break in attachment when subjected to a <**Insert value**> force.

D. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.

E. Fabricate openings and install sleeves in ceilings, floors, roof, and walls required by installation of products. Before proceeding with drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjacent condition.

F. Firestop Penetrations Made in Fire-Rated Assemblies: Comply with requirements in Section 078413 "Penetration Firestopping."

G. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 079200 "Joint Sealants."

H. Welding Requirements:

1. Restrict welding and burning to supports and bracing.
2. No equipment shall be cut or welded without approval. Welding or cutting will not be approved if there is risk of damage to adjacent Work.
3. Welding, where approved, shall be by inert-gas electric arc process and shall be performed by qualified welders according to applicable welding codes.
4. If requested on-site, show satisfactory evidence of welder certificates indicating ability to perform welding work intended.

I. Fastening Hardware:

1. Stillson wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.
2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
3. Lubricate threads of bolts, nuts and screws with graphite and oil before assembly.

J. If product locations are not indicated, install products in locations that are accessible and that will permit service and maintenance from floor, equipment platforms, or catwalks without removal of permanently installed furniture and equipment.

K. Corrosive Environments:

1. Avoid or limit use of materials in corrosive airstreams and environments, including, but not limited to, the following:

   a. Laboratory exhaust-air streams.
   b. Process exhaust-air streams.

2. When conduit is in contact with a corrosive airstream and environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment. Comply with requirements for installation of raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
3. Where instruments are located in a corrosive airstream and are not corrosive resistant from manufacturer, field install products in NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.7 WORKSTATION INSTALLATION

A. Desktop Workstations Installation:

If multiple desktop workstations with different requirements are required, revise subparagraphs below to match requirements in "Desktop Workstations" Article.

1. Install workstation(s) at location(s) directed by Owner.
2. Install multiple-receptacle power strip with cord for use in connecting multiple workstation components to a single duplex electrical power receptacle.
3. Install software on workstation(s) and verify software functions properly.
4. Develop Project-specific graphics, trends, reports, logs and historical database.
5. Power [**each**]workstation through a [**dedicated**]UPS unit. Locate UPS adjacent to workstation.

B. Portable Workstations Installation:

If multiple portable operator workstations with different requirements are required, revise subparagraphs below to match requirements in "Portable Operator Workstations" Article.

1. Turn over portable workstations to Owner at Substantial Completion.

2. Install software on workstation(s) and verify software functions properly.

C. Color Graphics Application:

1. Use system schematics indicated as starting point to create graphics.
2. Develop Project-specific library of symbols for representing system equipment and products.
3. Incorporate digital images of Project-completed installation into graphics where beneficial to enhance effect.
4. Submit sketch of graphic layout with description of all text for each graphic for Owner's[**and Architect's**] review before creating graphic using graphics software.
5. Seek Owner input in graphics development once using graphics software.
6. Final editing shall be done on-site with Owner's[**and Architect's**] review and feedback.
7. Refine graphics as necessary for Owner acceptance.
8. On receiving Owner acceptance, print a hard copy for inclusion in operation and maintenance manual. Prepare a scanned copy PDF file of each graphic and include with softcopy of DDC system operation and maintenance manual.

Retain "Wall-Mounted Portable Operator's Workstation Cabinet Installation" Paragraph below for applications requiring a cabinet to house and support portable operator workstations.

D. Wall-Mounted Portable Operator's Workstation Cabinet Installation:

Retain one of first two subparagraphs below.

1. Install wall-mounted portable operator's workstation cabinet(s) at location(s) indicated on Drawings.
2. Install wall-mounted portable operator's workstation cabinet(s) at following location(s) and at locations directed by Owner:

   a. Each mechanical room.
   b. Chiller room.
   c. Boiler room.
   d. <**Insert location**>.

3. Connect each cabinet to [**120-V, single-phase, 60Hz**] <**Insert power requirements**> field power source, and install single gang electrical box with [**NEMA WD 6, Type 20R duplex**] <**Insert receptacle type**> receptacle and metal cover plate in cabinet. Comply with requirements in Section 262726 "Wiring Devices."
4. Connect each cabinet to Ethernet network and install an Ethernet network port for connection to portable operator workstation Ethernet cable. Comply with requirements in Section 271513 "Communications Copper Horizontal Cabling."

Retain "POT Installation" Article below if operator access is provided at multiple locations and a portable operator workstation is not provided. Portable operator workstation is preferred because it provides operator with more capabilities.

3.8 POT INSTALLATION

Retain first paragraph below unless indicated on Drawings.

A. Install [**one**] [**two**] <**Insert quantity**> portable operator terminal(s).

B. Turn over POTs to Owner at Substantial Completion.

C. Install software on each POT and verify that software functions properly.

3.9 SERVER INSTALLATION

Retain one of first two paragraphs below if servers are not indicated on Drawings.

A. Install [**one**] [**two**] <**Insert quantity**> server(s) at location(s) directed by Owner.

B. Install number of servers required to suit requirements indicated. Review Project requirements and indicate layout of proposed location in Shop Drawings.

C. Install software indicated on server(s) and verify that software functions properly.

D. Develop Project-specific graphics, trends, reports, logs, and historical database.

E. Power servers through [**dedicated**]UPS unit. Locate UPS adjacent to server.

3.10 PRINTER INSTALLATION

A. Provide the following printer(s) at location(s) directed by Owner:

Retain list of printer types in four subparagraphs below if printers are not indicated on Drawings.

1. Black and White Laser: Quantity, [**one**] [**one per desktop workstation**] <**Insert quantity**>.
2. Color Laser: Quantity, [**one**] [**one per desktop workstation**] <**Insert quantity**>.
3. Color Inkjet: Quantity, [**one**] [**one per desktop workstation**] <**Insert quantity**>.
4. Dot Matrix: Quantity, [**one**] [**one per desktop workstation**] <**Insert quantity**>.

B. Install printer software on workstations and verify that software functions properly.

3.11 GATEWAY INSTALLATION

Design of each gateway should include an interoperability schedule showing each point or event with interface requirements defined for each.

For BACnet DDC systems, include an interoperability schedule showing each point or event on non-BACnet side that BACnet "client" will read, and each parameter that BACnet network will write to for BACnet services, or BIBBs defined in ASHRAE 135, Annex K.

A. Install gateways if required for DDC system communication interface requirements indicated.

1. Install gateway(s) required to suit indicated requirements.

   a. <**Insert requirements**>.

B. Test gateway to verify that communication interface functions properly.

3.12 ROUTER INSTALLATION

A. Install routers if required for DDC system communication interface requirements indicated.

1. Install router(s) required to suit indicated requirements.

a. <**Insert requirements**>.

B. Test router to verify that communication interface functions properly.

3.13 CONTROLLER INSTALLATION

A. Install controllers in enclosures to comply with indicated requirements.

B. Connect controllers to field power supply[**and to UPS units where indicated**].

C. Install controller with latest version of applicable software and configure to execute requirements indicated.

D. Test and adjust controllers to verify operation of connected I/O to achieve performance indicated requirements while executing sequences of operation.

E. Installation of Network Controllers:

1. Quantity and location of network controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
2. Install controllers in a protected location that is easily accessible by operators.
3. Top of controller shall be within [**72 inches**] [**84 inches**] <**Insert dimension**> of finished floor.

F. Installation of Programmable Application Controllers:

1. Quantity and location of programmable application controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
2. Install controllers in a protected location that is easily accessible by operators.
3. Top of controller shall be within [**72 inches**] [**84 inches**] <**Insert dimension**> of finished floor.

G. Application-Specific Controllers:

1. Quantity and location of application-specific controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
2. For controllers not mounted directly on equipment being controlled, install controllers in a protected location that is easily accessible by operators.

3.14 INSTALLATION OF WIRELESS ROUTERS FOR OPERATOR INTERFACE

A. Install wireless routers to achieve optimum performance and best possible coverage.

B. Mount wireless routers in a protected location that is within 60 inches of floor and easily accessible by operators.

C. Connect wireless routers to field power supply and to UPS units if network controllers are powered through UPS units.

D. Install wireless router with latest version of applicable software and configure wireless router with WPA2 security and password protection. Create access password with not less than 12 characters consisting of letters and numbers and at least one special character. Document password in operations and maintenance manuals for reference by operators.

E. Test and adjust wireless routers for proper operation with portable workstation and other wireless devices intended for use by operators.

3.15 ENCLOSURES INSTALLATION

A. Install the following items in enclosures, to comply with indicated requirements:

Retain applicable devices in subparagraphs below.

1. Gateways.
2. Routers.
3. Controllers.
4. Electrical power devices.
5. UPS units.
6. Relays.
7. Accessories.
8. Instruments.
9. Actuators
10. <**Insert devices**>.

B. Attach wall-mounted enclosures to wall using the following types of steel struts:

1. For NEMA 250, [**Type 1**] <**Insert type**> Enclosures: Use [**painted steel**] [**galvanized-steel**] [**corrosion-resistant-coated steel**] strut and hardware.
2. For NEMA 250, [**Type 4**] [**Type 4X**] <**Insert type**> Enclosures and Enclosures Located Outdoors: Use stainless-steel strut and hardware.
3. Install plastic caps on exposed cut edges of strut.

C. Align [**top**] [**or**] [**bottom**] of adjacent enclosures[**of like size**].

D. Install floor-mounted enclosures located [**in mechanical equipment rooms**]on concrete housekeeping pads. Attach enclosure legs using [**galvanized-**] [**or**] [**stainless-**]steel anchors.

Retain paragraph below to require wireways to connect between adjacent enclosures. Wireways provide a neat and easily accessible alternative to conduit, but they may come at a higher cost for specific installation.

E. Install continuous and fully accessible wireways to connect conduit, wire, and cable to multiple adjacent enclosures. Wireway used for application shall have protection equal to NEMA 250 rating of connected enclosures.

3.16 ELECTRIC POWER CONNECTIONS

A. Connect electrical power to DDC system products requiring electrical power connections.

B. Design of electrical power to products not indicated with electric power is delegated to DDC system provider and installing trade. Work shall comply with NFPA 70 and other requirements indicated.

C. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers" for electrical power circuit breakers.

D. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for electrical power conductors and cables.

E. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.

3.17 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identification products and installation.

Products in first paragraph below are described in Section 260553 "Identification for Electrical Systems."

B. Install [**self-adhesive labels**] [**laminated acrylic or melamine plastic signs**] with unique identification on face for each of the following:

1. Operator workstation.
2. Server.
3. Printer.
4. Gateway.
5. Router.
6. Protocol analyzer.
7. DDC controller.
8. Enclosure.
9. Electrical power device.
10. UPS unit.
11. Accessory.

C. Install unique instrument identification on face of each instrument connected to a DDC controller.

D. Install unique identification on face of each control [**damper**] [**and**] [**valve**] actuator connected to a DDC controller.

Retain first two paragraphs below to enhance locating products installed above ceilings.

E. Where product is installed above accessible tile ceiling, also install matching identification on face of ceiling grid located directly below.

F. Where product is installed above an inaccessible ceiling, also install identification on face of access door directly below.

G. Warning Labels and Signs:

1. Shall be permanently attached to equipment that can be automatically started by DDC control system.
2. Shall be located in highly visible location near power service entry points.

3.18 NETWORK INSTALLATION

Retain first paragraph below to require optical fiber cable when connecting networks across large distance.

A. Install optical fiber cable when connecting between the following network devices and when located in different buildings on campus, or when distance between devices exceeds <**Insert distance**>:

1. Operator workstations.
2. Operator workstations and network controllers.
3. Network controllers.
4. <**Insert network device**>.

B. Install balanced twisted pair [**or optical fiber**]cable when connecting between the following network devices[**located in same building**]:

1. Operator workstations.
2. Operator workstations and network controllers.
3. Network controllers.
4. <**Insert network device**>.

C. Install balanced twisted pair or copper cable (as required by equipment) when connecting between the following:

1. Gateways.
2. Gateways and network controllers or programmable application controllers.
3. Routers.
4. Routers and network controllers or programmable application controllers.
5. Network controllers and programmable application controllers.

6. Programmable application controllers.
7. Programmable application controllers and application-specific controllers.
8. Application-specific controllers.
9. <**Insert network device**>.

D. Install cable in continuous raceway.

1. Where indicated on Drawings, cable trays may be used for copper cable in lieu of conduit.

3.19 NETWORK NAMING AND NUMBERING

A. Coordinate with Owner and provide unique naming and addressing for networks and devices.

Retain "ASHRAE 135 Networks" Paragraph below for unique requirements to ASHRAE 135 networks.

B. ASHRAE 135 Networks:

1. MAC Address:

   a. Every network device shall have an assigned and documented MAC address unique to its network.
   b. Ethernet Networks: Document MAC address assigned at its creation.
   c. ARCNET or MS/TP networks: Assign from 00 to 64.

2. Network Numbering:

   a. Assign unique numbers to each new network.
   b. Provide ability for changing network number through device switches or operator interface.
   c. DDC system, with all possible connected LANs, can contain up to 65,534 unique networks.

3. Device Object Identifier Property Number:

   a. Assign unique device object identifier property numbers or device instances for each device network.
   b. Provide for future modification of device instance number by device switches or operator interface.
   c. LAN shall support up to 4,194,302 unique devices.

4. Device Object Name Property Text:

   a. Device object name property field shall support 32 minimum printable characters.
   b. Assign unique device "Object Name" property names with plain-English descriptive names for each device.

      1) Example 1: Device object name for device controlling boiler plant at Building 1000 would be "HW System B1000."
      2) Example 2: Device object name for a VAV terminal unit controller could be "VAV unit 102".

5. Object Name Property Text for Other Than Device Objects:

   a. Object name property field shall support 32 minimum printable characters.
   b. Assign object name properties with plain-English names descriptive of application.

      1) Example 1: "Zone 1 Temperature."
      2) Example 2 "Fan Start and Stop."

6. Object Identifier Property Number for Other Than Device Objects:

   a. Assign object identifier property numbers according to [**Drawings**] [**or**] [**tables**] indicated.
   b. If not indicated, object identifier property numbers may be assigned at Installer's discretion but must be approved by Owner in advance, be documented and be unique for like object types within device.

3.20 PIPING AND TUBING INSTALLATION

A. Above-Grade Pneumatic and Air Signal Piping and Tubing Installation:

1. Material Application:

Retain one of first two subparagraphs below. Retain first subparagraph for projects not requiring galvanized-steel pipe.

   a. Install copper tubing, except as follows:

      1) Tubing Exposed to View: Polyethylene tubing installed in raceways may be used in lieu of copper tubing.
      2) Concealed Tubing: Polyethylene tubing may be used in lieu of copper tubing when [**concealed behind accessible ceilings**] [**and**] [**concealed in walls and connecting wall-mounted instruments with recessed connections**].

   b. Install copper tubing for sizes up through [**NPS 1**] <**Insert size**> and install galvanized-steel pipe for larger sizes, except as follows:

      1) Tubing Exposed to View: Polyethylene tubing installed in raceways may be used in lieu of copper tubing where exposed to view.
      2) Concealed Tubing: Polyethylene tubing may be used in lieu of copper tubing when [**concealed behind accessible ceilings**] [**and**] [**concealed in walls and connecting wall-mounted instruments with recessed connections**].

   c. Install copper tubing[**, unless other accessible materials are indicated,**] for pneumatic main and control signals to instruments including, but not limited to, the following:

      1) Pneumatic actuators.
      2) I/P transducers.

3) Sensors.
4) Switches.
5) Transmitters.
6) <**Insert instrument**>.

d. Install copper tubing[**, unless other accessible materials are indicated,**] for air signals to instruments including, but not limited to, the following:

1) Sensors.
2) Switches.
3) Transmitters.
4) <**Insert instrument**>.

e. Install drawn-temper copper tubing, except within 36 inches of device terminations tubing shall be annealed-tempered copper tubing.
f. Install compression fittings to connect copper tubing to instruments, control devices, and accessories.
g. Install [**barbed**] [**or**] [**compression**] fittings to connect polyethylene tubing to instruments, control devices, and accessories.

2. Routing:

a. Do not expose tubing in finished spaces, such as spaces with ceilings; occupied spaces, offices, and conference rooms, unless expressly approved in writing by Architect. Tubing may be exposed in areas without ceilings.
b. Where tubing is installed in finished occupied spaces, install the tubing in surface metal raceway with appropriate fittings only where not feasible to conceal in wall, above ceiling or behind architectural enclosures or covers.
c. Install piping and tubing plumb and parallel to and at right angles with building construction.
d. Install multiple runs of tubing or piping in equally spaced parallel lines.
e. Piping and tubing shall not interfere with access to valves, equipment, duct and equipment access doors, or obstruct personnel access and passageways of any kind.
f. Coordinate with other trades before installation to prevent proposed piping and tubing from interfering with pipe, duct, terminal equipment, light fixtures, conduit and cable tray space. If changes to Shop Drawings are necessary due to field coordination, document changes on record Drawings.
g. Install vibration loops in copper tubing when connecting to instrument and actuators that vibrate.

3. Support:

a. According to MSS SP-69, Table 3, except support spacing shall not exceed 60 inches.
b. Support copper tubing with copper hangers, clips, and tube trays.
c. Do not use tape for support or dielectric isolation.
d. Install supports at each change in direction and at each branch take off.
e. Attached supports to building structure independent of work of other trades. Support from ducts, pipes, cable trays, and conduits is prohibited.

f. Attached support from building structure with threaded rods, structural shapes, or channel strut.
g. Install and brace supports to carry static load plus a safety margin, which will allow tubing to be serviced.
h. Brace supports to prevent lateral movement.
i. Paint steel support members that are not galvanized or zinc coated.
j. Support polyethylene tubing same as copper tubing.

4. Do not attach piping and tubing to equipment that may be removed frequently for maintenance or that may impart vibration and expansion from temperature change.

Retain first subparagraph below for additional protection.

5. Protect exposed tubing in mechanical equipment rooms from mechanical damage within [**76 inches**] [**84 inches**] [**96 inches**] <**Insert dimension**> above floor. Use aluminum channel reversed and secured over tubing to protect tubing from damage.
6. Joining and Makeup:

a. Where joining and mating dissimilar metals where galvanic action could occur, install dielectric isolation.
b. Install a dirt leg with an isolation valve and threaded plug at each main air, connection to a panel, pneumatic pilot positioner and PRV station.
c. Make threaded joints for connecting to instrument equipment with connectors with a compression tubing connector on one end and threaded connection on other end.
d. Make tubing bends with a tube-bending tool. Hard bends, wrinkled or flattened bends are unacceptable.
e. Install tube fittings according to manufacturer's written instructions.
f. Do not make tubing connections to a fitting before completing makeup of the connection.
g. Align tubing with the fitting. Avoid springing tube into position, as this may result in excessive stress on both tubing and fitting with possible resulting leaks.
h. Do not install fittings close to a bend. A length of straight tubing, not deformed by bending, is required for a proper connection.
i. Check tubing for correct diameter and wall thickness.
j. Tube ends shall be cut square and deburred. Exercise care during cutting to keep tubing round.
k. Thread pipe on a threading machine. Ream inner edges of pipe ends, file and grind to remove burrs.
l. Wrap pipe threads of fittings on pneumatic lines with a single wrap of PTFE tape.
m. Protect piping and tubing from entrance of foreign matter.

7. Conduit in which nonmetallic tubing is installed shall not exceed 50 percent fill. Support conduit according to NFPA 70 unless otherwise indicated.

B. Below-Grade Pneumatic and Air Signal Piping and Tubing Installation:

1. Install tubing below grade in a continuous 4-inch, Schedule 80, PVC conduit.
2. Install at a depth of at least 24 inches below finished grade.
3. Install tubing in raceways dedicated to tubing. Do not combine electrical conductors and tubing in raceways.

C. Identify piping and tubing as follows:

1. Every 50 feet of straight run.
2. At least once for each branch within 36 inches of main tee.
3. At each change in direction.
4. Within 36 inches of each ceiling, floor, roof and wall penetration.
5. Where exposed to and where concealed from view, including above ceiling plenums, shafts, and chases.
6. At each valve.
7. Mark each instrument tube connection with a number-coded identification. Each unique tube shall have same unique number at instrument connection and termination at opposite end of tube.

D. Isolation Valves Installation:

1. Install valves full size of piping and tubing.
2. Install at the following locations:

    a. At each branch.
    b. Before and after each PRV.
    c. Before and after each air dryer.
    d. At each control device.

3. Valves shall be located to be readily accessible from floor.

E. Process Tubing Installation:

1. Install process tubing for signal to instruments in liquid and steam systems. Instruments include, but are not limited to, the following:

    a. Meters.
    b. Sensors.
    c. Switches.
    d. Transmitters.

2. Support tubing according to MSS SP-69, Table 3, but at intervals no less than 60 inches.
3. Install NPS 1/2 process tubing for industrial-grade sensors, transmitters, and switches. Install stainless-steel bushings where required.
4. Make tubing bends with a bending tool. Flattened or wrinkled bends are unacceptable.
5. Support tubing independent of other trades.
6. Route tubing parallel to and at right angles to building construction.
7. Install tubing concealed in areas with ceilings.
8. Install a dirt leg with an isolation valve and threaded plug in drain valve at each connection to a transmitter and switch.
9. Insulate process piping connected to hot water and steam systems for personnel protection if the surface temperature exceeds 120 deg F. Only insulate piping within maintenance personnel reach from floor, platform, or catwalk.
10. Wrap pipe threads of fitting in process tubing with service temperatures below 350 deg F with a single wrap of PTFE tape.
11. Coat pipe threads of fittings on process tubing in services with temperatures exceeding 350 deg F with pipe compound before being made up to reduce the possibility of galling.
12. Do not make tubing connections to a fitting before completing makeup of the connection.

13. Check tubing for correct diameter and wall thickness. Cut the tube ends square and deburred. Exercise care during cutting to keep tubing round.
14. Do not install fittings close to a bend. A length of straight tubing, not deformed by bending, is required for a proper connection.
15. Align tubing with fitting when installed. Avoid springing tube into position.
16. Install tubing with extreme care exercised to keep foreign matter out of system. Open tubing ends shall be kept plugged to keep out dust, dirt and moisture.
17. Do not attach tubing to equipment that may be removed frequently for maintenance or may impart vibration and expansion from temperature change.

Retain subparagraph below for additional protection.

18. Protect exposed tubing in mechanical equipment rooms from inadvertent mechanical damage within [**76 inches**] [**84 inches**] [**96 inches**] <**Insert dimension**> above floor. Use aluminum channel reversed and secured over tubing to protect tubing from damage.

F. Isolation Valves Installation:

1. Install valves full size of piping and tubing.
2. Install isolation valves at the following locations:

   a. Process connection.
   b. Inlet to each instrument including, sensors, transmitters, switches, gages, and other control devices.

3. Locate valves to be readily accessible from floor.

3.21 CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION

A. Comply with NECA 1.

B. Wire and Cable Installation:

1. Comply with installation requirements in Section 260523 "Control-Voltage Electrical Power Cables."
2. Comply with installation requirements in Section 271313 "Communications Copper Backbone Cabling."
3. Comply with installation requirements in Section 271513 "Communications Copper Horizontal Cabling."

Requirements below are in addition to those specified in the Division 26 and 27 cabling sections.

4. Install cables with protective sheathing that is waterproof and capable of withstanding continuous temperatures of 90 deg C with no measurable effect on physical and electrical properties of cable.

   a. Provide shielding to prevent interference and distortion from adjacent cables and equipment.

5. Terminate wiring in a junction box.

   a. Clamp cable over jacket in junction box.

b. Individual conductors in the stripped section of the cable shall be slack between the clamping point and terminal block.

6. Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.
7. Install signal transmission components according to IEEE C2, REA Form 511a, NFPA 70, and as indicated.
8. Use shielded cable to transmitters.
9. Use shielded cable to temperature sensors.
10. Perform continuity and meager testing on wire and cable after installation.

C. Conduit Installation:

1. Comply with Section "260533 "Raceways and Boxes for Electrical Systems" for control-voltage conductors.
2. Comply with Section 270528 "Pathways for Communications Systems" for balanced twisted pair cabling and optical fiber installation.

3.22 OPTICAL FIBER CABLE SYSTEM INSTALLATION

A. Comply with installation requirements in Section 271323 "Communications Optical Fiber Backbone Cabling."

B. Comply with installation requirements in Section 271523 "Communications Optical Fiber Horizontal Cabling."

3.23 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Testing of Pneumatic and Air-Signal Tubing:

    a. Test for leaks and obstructions.
    b. Disconnect each pipe and tubing line before a test is performed, and blowout dust, dirt, trash, condensate and other foreign materials with compressed air. Use commercially pure compressed air or nitrogen as distributed in gas cylinders. Air from an oil-free compressor with an air dryer is an acceptable alternative for the test.
    c. After foreign matter is expelled and line is free from obstructions, plug far end of tubing run.
    d. Connect a pressure source to near end of run with a needle valve between air supply and tubing run.
    e. Connect a pressure gage accurate to within 0.5 percent of test between the shutoff needle valve and tubing run under test.
    f. For system pressures above 30 psig, apply a pressure of 1.5 times operating pressure. Record pressure in tubing run every 10 minutes for one hour. Allowable drop in pressure in one-hour period shall not exceed 1 psig.
    g. For system pressures 30 psig and below, apply a pressure of 2.0 times operating pressure to piping and tubing run. Record pressure in tubing run every 5 minutes for one hour. Allowable drop in pressure in one-hour period shall not exceed 0.5 psig.

D. Testing:

1. Perform preinstallation, in-progress, and final tests, supplemented by additional tests, as necessary.
2. Preinstallation Cable Verification: Verify integrity and serviceability for new cable lengths before installation. This assurance may be provided by using vendor verification documents, testing, or other methods. As a minimum, furnish evidence of verification for cable attenuation and bandwidth parameters.
3. In-Progress Testing: Perform standard tests for correct pair identification and termination during installation to ensure proper installation and cable placement. Perform tests in addition to those specified if there is any reason to question condition of material furnished and installed. Testing accomplished is to be documented by agency conducting tests. Submit test results for Project record.
4. Final Testing: Perform final test of installed system to demonstrate acceptability as installed. Testing shall be performed according to a test plan supplied by DDC system manufacturer. Defective Work or material shall be corrected and retested. As a minimum, final testing for cable system, including spare cable, shall verify conformance of attenuation, length, and bandwidth parameters with performance indicated.
5. Test Equipment: Use an optical fiber time domain reflectometer for testing of length and optical connectivity.
6. Test Results: Record test results and submit copy of test results for Project record.

3.24 DDC SYSTEM I/O CHECKOUT PROCEDURES

A. Check installed products before continuity tests, leak tests and calibration.

B. Check instruments for proper location and accessibility.

C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.

D. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material and support.

E. For pneumatic products, verify that air supply for each product is properly installed.

F. Control Damper Checkout:

1. For pneumatic dampers, verify that pressure gages are provided in each air line to damper actuator and positioner.
2. Verify that control dampers are installed correctly for flow direction.
3. Verify that proper blade alignment, either parallel or opposed, has been provided.
4. Verify that damper frame attachment is properly secured and sealed.
5. Verify that damper actuator and linkage attachment is secure.
6. Verify that actuator wiring is complete, enclosed and connected to correct power source.
7. Verify that damper blade travel is unobstructed.

G. Control Valve Checkout:

1. For pneumatic valves, verify that pressure gages are provided in each air line to valve actuator and positioner.
2. Verify that control valves are installed correctly for flow direction.
3. Verify that valve body attachment is properly secured and sealed.
4. Verify that valve actuator and linkage attachment is secure.
5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
6. Verify that valve ball, disc or plug travel is unobstructed.
7. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.

H. Instrument Checkout:

1. Verify that instrument is correctly installed for location, orientation, direction and operating clearances.
2. Verify that attachment is properly secured and sealed.
3. Verify that conduit connections are properly secured and sealed.
4. Verify that wiring is properly labeled with unique identification, correct type and size and is securely attached to proper terminals.
5. Inspect instrument tag against approved submittal.
6. For instruments with tubing connections, verify that tubing attachment is secure and isolation valves have been provided.
7. For flow instruments, verify that recommended upstream and downstream distances have been maintained.

8. For temperature instruments:

   a. Verify sensing element type and proper material.
   b. Verify length and insertion.

3.25 DDC SYSTEM I/O ADJUSTMENT, CALIBRATION AND TESTING:

A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.

B. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.

C. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.

D. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.

E. Provide diagnostic and test equipment for calibration and adjustment.

F. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. An installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.

G. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.

H. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.

I. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

J. Analog Signals:

   1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
   2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
   3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

K. Digital Signals:

   1. Check digital signals using a jumper wire.
   2. Check digital signals using an ohmmeter to test for contact making or breaking.

L. Control Dampers:

   1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.

2. Stroke control dampers with pilot positioners. Adjust damper and positioner following manufacturer's recommended procedure, so damper is 100 percent closed, 50 percent closed and 100 percent open at proper air pressure.
3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
4. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

M. Control Valves:

1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
2. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed and 100 percent open at proper air pressures.
3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
4. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

N. Meters: Check sensors at zero, 50, and 100 percent of Project design values.

O. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

P. Switches: Calibrate switches to make or break contact at set points indicated.

Q. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.

3.26 DDC SYSTEM CONTROLLER CHECKOUT

A. Verify power supply.

1. Verify voltage, phase and hertz.
2. Verify that protection from power surges is installed and functioning.
3. Verify that ground fault protection is installed.
4. If applicable, verify if connected to UPS unit.
5. If applicable, verify if connected to a backup power source.
6. If applicable, verify that power conditioning units, transient voltage suppression and high-frequency noise filter units are installed.

B. Verify that wire and cabling is properly secured to terminals and labeled with unique identification.

C. Verify that spare I/O capacity is provided.

3.27 DDC CONTROLLER I/O CONTROL LOOP TESTS

A. Testing:

1. Test every I/O point connected to DDC controller to verify that safety and operating control set points are as indicated and as required to operate controlled system safely and at optimum performance.
2. Test every I/O point throughout its full operating range.
3. Test every control loop to verify operation is stable and accurate.
4. Adjust control loop proportional, integral and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.
5. Test and adjust every control loop for proper operation according to sequence of operation.
6. Test software and hardware interlocks for proper operation. Correct deficiencies.
7. Operate each analog point at the following:

   a. Upper quarter of range.
   b. Lower quarter of range.
   c. At midpoint of range.

8. Exercise each binary point.
9. For every I/O point in DDC system, read and record each value at operator workstation, at DDC controller and at field instrument simultaneously. Value displayed at operator workstation, at DDC controller and at field instrument shall match.
10. Prepare and submit a report documenting results for each I/O point in DDC system and include in each I/O point a description of corrective measures and adjustments made to achieve desire results.

3.28 DDC SYSTEM VALIDATION TESTS

A. Perform validation tests before requesting final review of system. Before beginning testing, first submit Pretest Checklist and Test Plan.

B. After approval of Test Plan, execute all tests and procedures indicated in plan.

C. After testing is complete, submit completed test checklist.

D. Pretest Checklist: Submit the following list with items checked off once verified:

1. Detailed explanation for any items that are not completed or verified.
2. Required mechanical installation work is successfully completed and HVAC equipment is working correctly.
3. HVAC equipment motors operate below full-load amperage ratings.
4. Required DDC system components, wiring, and accessories are installed.
5. Installed DDC system architecture matches approved Drawings.
6. Control electric power circuits operate at proper voltage and are free from faults.
7. Required surge protection is installed.
8. DDC system network communications function properly, including uploading and downloading programming changes.

Retain first subparagraph below if applicable to Project.

9. Using BACnet protocol analyzer, verify that communications are error free.
10. Each controller's programming is backed up.
11. Equipment, products, tubing, wiring cable and conduits are properly labeled.
12. All I/O points are programmed into controllers.
13. Testing, adjusting and balancing work affecting controls is complete.
14. Dampers and actuators zero and span adjustments are set properly.
15. Each control damper and actuator goes to failed position on loss of power.
16. Valves and actuators zero and span adjustments are set properly.
17. Each control valve and actuator goes to failed position on loss of power.
18. Meter, sensor and transmitter readings are accurate and calibrated.
19. Control loops are tuned for smooth and stable operation.
20. View trend data where applicable.
21. Each controller works properly in standalone mode.
22. Safety controls and devices function properly.
23. Interfaces with fire-alarm system function properly.
24. Electrical interlocks function properly.
25. Operator workstations and other interfaces are delivered, all system and database software is installed, and graphic are created.
26. Record Drawings are completed.

E. Test Plan:

1. Prepare and submit a validation test plan including test procedures for performance validation tests.
2. Test plan shall address all specified functions of DDC system and sequences of operation.
3. Explain detailed actions and expected results to demonstrate compliance with requirements indicated.
4. Explain method for simulating necessary conditions of operation used to demonstrate performance.
5. Include a test checklist to be used to check and initial that each test has been successfully completed.
6. Submit test plan documentation [**10**] [**20**] <**Insert number**> business days before start of tests.

F. Validation Test:

1. Verify operating performance of each I/O point in DDC system.

   a. Verify analog I/O points at operating value.
   b. Make adjustments to out-of-tolerance I/O points.

      1) Identify I/O points for future reference.
      2) Simulate abnormal conditions to demonstrate proper function of safety devices.
      3) Replace instruments and controllers that cannot maintain performance indicated after adjustments.

2. Simulate conditions to demonstrate proper sequence of control.
3. Readjust settings to design values and observe ability of DDC system to establish desired conditions.

4. After 24 Hours following Initial Validation Test:

    a. Re-check I/O points that required corrections during initial test.
    b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.

5. After 24 Hours of Second Validation Test:

    a. Re-check I/O points that required corrections during second test.
    b. Continue validation testing until I/O point is normal on two consecutive tests.

6. Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
7. After validation testing is complete, prepare and submit a report indicating all I/O points that required correction and how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.

G. DDC System Response Time Test:

1. Simulate HLC.

    a. Heavy load shall be an occurrence of [**50**] <**Insert number**> percent of total connected binary COV, one-half of which represent an "alarm" condition, and [**50**] <**Insert number**> percent of total connected analog COV, one-half of which represent an "alarm" condition, that are initiated simultaneously on a one-time basis.

2. Initiate 10 successive occurrences of HLC and measure response time to typical alarms and status changes.
3. Measure with a timer having at least 0.1-second resolution and 0.01 percent accuracy.
4. Purpose of test is to demonstrate DDC system, as follows:

    a. Reaction to COV and alarm conditions during HLC.
    b. Ability to update DDC system database during HLC.

5. Passing test is contingent on the following:

    a. Alarm reporting at printer beginning no more than [**two**] <**Insert number**> seconds after the initiation (time zero) of HLC.
    b. All alarms, both binary and analog, are reported and printed; none are lost.
    c. Compliance with response times specified.

6. Prepare and submit a report documenting HLC tested and results of test including time stamp and print out of all alarms.

H. DDC System Network Bandwidth Test:

1. Test network bandwidth usage on all DDC system networks to demonstrate bandwidth usage under DDC system normal operating conditions and under simulated HLC.
2. To pass, none of DDC system networks shall use more than 70 percent of available bandwidth under normal and HLC operation.

3.29 DDC SYSTEM WIRELESS NETWORK VERIFICATION

A. DDC system Installer shall design wireless DDC system networks to comply with performance requirements indicated.

B. Installer shall verify wireless network performance through field testing and shall document results in a field test report.

C. Testing and verification of all wireless devices shall include, but not be limited to, the following:

1. Speed.
2. Online status.
3. Signal strength.

3.30 FINAL REVIEW

A. Submit written request to Architect [**and**] [**Construction Manager**] when DDC system is ready for final review. Written request shall state the following:

1. DDC system has been thoroughly inspected for compliance with contract documents and found to be in full compliance.
2. DDC system has been calibrated, adjusted and tested and found to comply with requirements of operational stability, accuracy, speed and other performance requirements indicated.
3. DDC system monitoring and control of HVAC systems results in operation according to sequences of operation indicated.
4. DDC system is complete and ready for final review.

B. Review by [**Architect**] [**and**] [**Construction Manager**] shall be made after receipt of written request. A field report shall be issued to document observations and deficiencies.

C. Take prompt action to remedy deficiencies indicated in field report and submit a second written request when all deficiencies have been corrected. Repeat process until no deficiencies are reported.

D. Should more than two reviews be required, DDC system manufacturer and Installer shall compensate entity performing review for total costs, labor and expenses, associated with third and subsequent reviews. Estimated cost of each review shall be submitted and approved by DDC system manufacturer and Installer before making the review.

E. Prepare and submit closeout submittals[**and begin procedures indicated in "Extended Operation Test" Article**] when no deficiencies are reported.

F. A part of DDC system final review shall include a demonstration to parties participating in final review.

1. Provide staff familiar with DDC system installed to demonstrate operation of DDC system during final review.

2. Provide testing equipment to demonstrate accuracy and other performance requirements of DDC system that is requested by reviewers during final review.
3. Demonstration shall include, but not be limited to, the following:

Subparagraphs below are examples only and must be revised to suit Project.

a. Accuracy and calibration of [**10**] [**20**] <**Insert number**> I/O points randomly selected by reviewers. If review finds that some I/O points are not properly calibrated and not satisfying performance requirements indicated, additional I/O points may be selected by reviewers until total I/O points being reviewed that satisfy requirements equals quantity indicated.
b. HVAC equipment and system hardwired and software safeties and life-safety functions are operating according to sequence of operation. Up to [**10**] [**20**] <**Insert number**> I/O points shall be randomly selected by reviewers. Additional I/O points may be selected by reviewers to discover problems with operation.
c. Correct sequence of operation after electrical power interruption and resumption after electrical power is restored for randomly selected HVAC systems.
d. Operation of randomly selected dampers and valves in normal-on, normal-off and failed positions.
e. Reporting of alarm conditions for randomly selected alarms, including different classes of alarms, to ensure that alarms are properly received by operators and operator workstations.
f. Trends, summaries, logs and reports set-up for Project.
g. For up to [**three**] <**Insert number**> HVAC systems randomly selected by reviewers, use graph trends to show that sequence of operation is executed in correct manner and that HVAC systems operate properly through complete sequence of operation including different modes of operations indicated. Show that control loops are stable and operating at set points and respond to changes in set point of 20 percent or more.
h. Software's ability to communicate with controllers, operator workstations, uploading and downloading of control programs.
i. Software's ability to edit control programs off-line.
j. Data entry to show Project-specific customizing capability including parameter changes.
k. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
l. Execution of digital and analog commands in graphic mode.
m. Spreadsheet and curve plot software and its integration with database.
n. Online user guide and help functions.
o. Multitasking by showing different operations occurring simultaneously on four quadrants of split screen.
p. System speed of response compared to requirements indicated.
q. For Each [**Network**] [**and**] [**Programmable Application**] Controller:

1) Memory: Programmed data, parameters, trend and alarm history collected during normal operation is not lost during power failure.
2) Operator Interface: Ability to connect directly to each type of digital controller with a portable workstation and mobile device. Show that maintenance personnel interface tools perform as indicated in manufacturer's technical literature.

3) Standalone Ability: Demonstrate that controllers provide stable and reliable standalone operation using default values or other method for values normally read over network.
4) Electric Power: Ability to disconnect any controller safely from its power source.
5) Wiring Labels: Match control drawings.
6) Network Communication: Ability to locate a controller's location on network and communication architecture matches Shop Drawings.
7) Nameplates and Tags: Accurate and permanently attached to control panel doors, instrument, actuators and devices.

r. For Each Operator Workstation:

1) I/O points lists agree with naming conventions.
2) Graphics are complete.
3) UPS unit, if applicable, operates.

s. Communications and Interoperability: Demonstrate proper interoperability of data sharing, alarm and event management, trending, scheduling, and device and network management.[**Use ASHRAE 135 protocol analyzer to help identify devices, view network traffic, and verify interoperability.**] Requirements must be met even if only one manufacturer's equipment is installed.

1) Data Presentation: On each operator workstation, demonstrate graphic display capabilities.
2) Reading of Any Property: Demonstrate ability to read and display any used readable object property of any device on network.
3) Set Point and Parameter Modifications: Show ability to modify set points and tuning parameters indicated.[**Modifications are made with messages and write services initiated by an operator using workstation graphics, or by completing a field in a menu with instructional text.**]
4) Peer-to-Peer Data Exchange: Network devices are installed and configured to perform without need for operator intervention to implement Project sequence of operation and to share global data.
5) Alarm and Event Management: Alarms and events are installed and prioritized according to Owner. Demonstrate that time delays and other logic are set up to avoid nuisance tripping. Show that operators with sufficient privileges are permitted.
6) Schedule Lists: Schedules are configured for start and stop, mode change, occupant overrides, and night setback as defined in sequence of operations.
7) Schedule Display and Modification: Ability to display any schedule with start and stop times for calendar year. Show that all calendar entries and schedules are modifiable from any connected operator workstation by an operator with sufficient privilege.
8) Archival Storage of Data: Data archiving is handled by operator workstation and server and local trend archiving and display is accomplished.
9) Modification of Trend Log Object Parameters: Operator with sufficient privilege can change logged data points, sampling rate, and trend duration.
10) Device and Network Management:

a) Display of network device status.

b) Display of BACnet Object Information.
c) Silencing devices transmitting erroneous data.
d) Time synchronization.
e) Remote device re-initialization.
f) Backup and restore network device programming and master database(s).
g) Configuration management of routers.

t. <**Insert additional requirements**>.

3.31 EXTENDED OPERATION TEST

Retain this article when documentation of proper DDC system operation over an extended operating period is required. Consult Owner to confirm if test is applicable due to added cost.

A. Extended operation test is intended to simulate normal operation of DDC system by Owner.

B. Operate DDC system for an operating period of [**14**] [**21**] [**28**] <**Insert number**> consecutive calendar days following Substantial Completion. Coordinate exact start date of testing with Owner.

C. Provide an operator familiar with DDC system installed to man an operator workstation [**while on-site**]during eight hours of each normal business day occurring during operating period.

D. During operating period, DDC system shall demonstrate correct operation and accuracy of monitored and controlled points as well as operation capabilities of sequences, logs, trends, reports, specialized control algorithms, diagnostics, and other software indicated.

1. Correct defects of hardware and software when it occurs.

E. Definition of Failures and Downtime during Operating Period:

1. Failed I/O point constituting downtime is an I/O point failing to perform its intended function consistently and a point physically failed due to hardware and software.
2. Downtime is when any I/O point in DDC system is unable to fulfill its' required function.
3. Downtime shall be calculated as elapsed time between a detected point failure as confirmed by an operator and time point is restored to service.
4. Maximum time interval allowed between DDC system detection of failure occurrence and operator confirmation shall be 0.5 hours.
5. Downtime shall be logged in hours to nearest 0.1 hour.
6. Power outages shall not count as downtime, but shall suspend test hours unless systems are provided with UPS and served through a backup power source.
7. Hardware or software failures caused by power outages shall count as downtime.

F. During operating period, log downtime and operational problems are encountered.

1. Identify source of problem.
2. Provide written description of corrective action taken.
3. Record duration of downtime.
4. Maintain log showing the following:

a. Time of occurrence.
b. Description of each occurrence and pertinent written comments for reviewer to understand scope and extent of occurrence.
c. Downtime for each failed I/O point.
d. Running total of downtime and total time of I/O point after each problem has been restored.

5. Log shall be available to Owner for review at any time.

G. For DDC system to pass extended operation test, total downtime shall not exceed [**1**] [**2**] <**Insert number**> percent of total point-hours during operating period.

1. Failure to comply with minimum requirements of passing at end of operating period indicated shall require that operating period be extended one consecutive day at a time until DDC system passes requirement.

H. Evaluation of DDC system passing test shall be based on the following calculation:

1. Downtime shall be counted on a point-hour basis where total number of DDC system point-hours is equal to total number of I/O points in DDC system multiplied by total number of hours during operating period.
2. One point-hour of downtime is one I/O point down for one hour. Three points down for five hours is a total of 15 point-hours of downtime. Four points down for one-half hour is 2 point-hours of downtime.
3. Example Calculation: Maximum allowable downtime for 30-day test when DDC system has 1000 total I/O points (combined analog and binary) and has passing score of 1 percent downtime is computed by 30 days x 24 h/day x 1000 points x 1 percent equals 7200 point-hours of maximum allowable downtime.

I. Prepare test and inspection reports.

3.32 ADJUSTING

A. Occupancy Adjustments: When requested within [**12**] <**Insert number**> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <**Insert number**> visits to Project during other-than-normal occupancy hours for this purpose.

3.33 MAINTENANCE SERVICE

Verify with Owner that maintenance service is required for Project.

A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include [**three**] [**six**] [**nine**] [**12**] <**Insert number**> months' full maintenance by DDC system manufacturer's authorized service representative. Include [**monthly**] [**quarterly**] [**semiannual**] [**annual**] preventive maintenance, repair or replacement of worn or defective components, cleaning, calibration and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.34 SOFTWARE SERVICE AGREEMENT

Services in this article may not be allowed for publicly funded projects.

A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for [**one**] [**two**] <**Insert number**> year(s).

B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within [**one**] [**two**] <**Insert number**> year(s) from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.

1. Upgrade Notice: At least [**30**] <**Insert number**> days to allow Owner to schedule and access system and to upgrade computer equipment if necessary.

3.35 DEMONSTRATION

Revise this article to suit scope of DDC system for Project. Not all requirements indicated may be applicable.

A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train Owner's maintenance personnel to adjust, operate, and maintain DDC system.

B. Extent of Training:

1. Base extent of training on scope and complexity of DDC system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
2. Inform Owner of anticipated training requirements if more than minimum training requirements are indicated.
3. Minimum Training Requirements:

Revise subparagraphs below to suit unique requirements of DDC system and other Project requirements. Consult Owner for assistance in establishing minimum requirements.

a. Provide not less than [**five**] [**10**] [**15**] <**Insert number**> days of training total.
b. Stagger training over multiple training classes to accommodate Owner's requirements. All training shall occur before end of warranty period.
c. Total days of training shall be broken into not more than [**two**] [**three**] [**four**] <**Insert number**> separate training classes.
d. Each training class shall be not less than [**one**] [**two**] [**three**] <**Insert number**> consecutive day(s).

C. Training Schedule:

1. Schedule training with Owner [**20**] <**Insert number**> business days before expected Substantial Completion.
2. Schedule training to provide Owner with at least [**10**] [**15**] [**20**] <**Insert number**> business days of notice in advance of training.

3. Training shall occur within normal business hours at a mutually agreed on time. Unless otherwise agreed to, training shall occur Monday through Friday, except on U.S. Federal holidays, with two morning sessions and two afternoon sessions. Each morning session and afternoon session shall be split in half with [**15**] [**30**] <**Insert number**>-minute break between sessions. Morning and afternoon sessions shall be separated by [**30**] [**60**] <**Insert number**>-minute lunch period. Training, including breaks and excluding lunch period, shall not exceed [**eight**] <**Insert number**> hours per day.
4. Provide staggered training schedule as requested by Owner.

D. Training Attendee List and Sign-in Sheet:

1. Request from Owner in advance of training a proposed attendee list with name, phone number and e-mail address.
2. Provide a preprinted sign-in sheet for each training session with proposed attendees listed and no fewer than six blank spaces to add additional attendees.
3. Preprinted sign-in sheet shall include training session number, date and time, instructor name, phone number and e-mail address, and brief description of content to be covered during session. List attendees with columns for name, phone number, e-mail address and a column for attendee signature or initials.
4. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
5. At end of each training day, send Owner an e-mail with an attachment of scanned copy (PDF) of circulated sign-in sheet for each session.

E. Training Attendee Headcount:

1. Plan in advance of training for [**two**] [**three**] [**five**] <**Insert number**> attendees.
2. Make allowance for Owner to add up to [**one**] [**two**] <**Insert number**> attendee(s) at time of training.
3. Headcount may vary depending on training content covered in session. Attendee access may be restricted to some training content for purposes of maintaining system security.

F. Training Attendee Prior Knowledge: For guidance in planning required training and instruction, assume attendees have the following:

Revise subparagraphs below to suit Owner personnel being trained. Consult Owner for assistance.

1. [**High school**] [**High school and technical school**] [**High school and four-year college**] <**Insert level**> education and degree.
2. [**Basic**] [**Intermediate**] [**Advanced**] user knowledge of computers and office applications.
3. [**Basic**] [**Intermediate**] [**Advanced**] knowledge of HVAC systems.
4. [**Basic**] [**Intermediate**] [**Advanced**] knowledge of DDC systems.
5. [**Basic**] [**Intermediate**] [**Advanced**] knowledge of DDC system and products installed.

G. Attendee Training Manuals:

1. Provide each attendee with a color hard copy of all training materials and visual presentations.

2. Hard-copy materials shall be organized in a three-ring binder with table of contents and individual divider tabs marked for each logical grouping of subject matter. Organize material to provide space for attendees to take handwritten notes within training manuals.
3. In addition to hard-copy materials included in training manual, provide each binder with a sleeve or pocket that includes a DVD or flash drive with PDF copy of all hard-copy materials.

H. Instructor Requirements:

1. One or multiple qualified instructors, as required, to provide training.
2. Instructors shall have not less than [**five**] <**Insert number**> years of providing instructional training on not less than [**five**] <**Insert number**> past projects with similar DDC system scope and complexity to DDC system installed.

I. Organization of Training Sessions:

1. Organize training sessions into logical groupings of technical content and to reflect different levels of operators having access to system. Plan training sessions to accommodate the following three levels of operators:

    a. Daily operators.
    b. Advanced operators.
    c. System managers and administrators.

2. Plan and organize training sessions to group training content to protect DDC system security. Some attendees may be restricted to some training sessions that cover restricted content for purposes of maintaining DDC system security.

J. Training Outline:

1. Submit training outline for Owner review at least [**10**] <**Insert number**> business day before scheduling training.
2. Outline shall include a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session and synopses for each lesson planned.

K. On-Site Training:

1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power and data connectivity for instructor and each attendee.
2. Instructor shall provide training materials, projector and other audiovisual equipment used in training.
3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. On-site training shall include regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration and service requirements.
5. Operator workstation provided with DDC system shall be used in training. If operator workstation is not indicated, provide a temporary workstation to convey training content.

L. Off-Site Training:

1. Provide conditioned training rooms and workspace with ample tables desks or tables, chairs, power and data connectivity for each attendee.

Retain first subparagraph below only if DDC system is capable of remote access.

2. Provide capability to remotely access to Project DDC system for use in training.
3. Provide a workstation for use by each attendee.

M. Training Content for Daily Operators:

Subparagraphs below are examples only and must be revised to suit Project.

1. Basic operation of system.
2. Understanding DDC system architecture and configuration.
3. Understanding each unique product type installed including performance and service requirements for each.
4. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm and each unique optimization routine.
5. Operating operator workstations, printers and other peripherals.
6. Logging on and off system.
7. Accessing graphics, reports and alarms.
8. Adjusting and changing set points and time schedules.
9. Recognizing DDC system malfunctions.
10. Understanding content of operation and maintenance manuals including control drawings.
11. Understanding physical location and placement of DDC controllers and I/O hardware.
12. Accessing data from DDC controllers.
13. Operating portable operator workstations.
14. Review of DDC testing results to establish basic understanding of DDC system operating performance and HVAC system limitations as of Substantial Completion.
15. Running each specified report and log.
16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
18. Executing digital and analog commands in graphic mode.
19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.
20. Demonstrating DDC system performance through trend logs and command tracing.
21. Demonstrating scan, update, and alarm responsiveness.
22. Demonstrating spreadsheet and curve plot software, and its integration with database.
23. Demonstrating on-line user guide, and help function and mail facility.
24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
25. Demonstrating the following for HVAC systems and equipment controlled by DDC system:

    a. Operation of HVAC equipment in normal-off, -on and failed conditions while observing individual equipment, dampers and valves for correct position under each condition.

b. For HVAC equipment with factory-installed software, show that integration into DDC system is able to communicate with DDC controllers or gateways, as applicable.
c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and unoccupied modes, warm-up and cool-down cycles and other modes of operation indicated.
d. Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
f. Each control loop responds to set point adjustment and stabilizes within time period indicated.
g. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.

26. <**Insert requirement**>.

N. Training Content for Advanced Operators:

Subparagraphs below are examples only and must be revised to suit Project.

1. Making and changing workstation graphics.
2. Creating, deleting and modifying alarms including annunciation and routing.
3. Creating, deleting and modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
4. Creating, deleting and modifying reports.
5. Creating, deleting and modifying points.
6. Creating, deleting and modifying programming including ability to edit control programs off-line.
7. Creating, deleting and modifying system graphics and other types of displays.
8. Adding DDC controllers and other network communication devices such as gateways and routers.
9. Adding operator workstations.
10. Performing DDC system checkout and diagnostic procedures.
11. Performing DDC controllers operation and maintenance procedures.
12. Performing operator workstation operation and maintenance procedures.
13. Configuring DDC system hardware including controllers, workstations, communication devices and I/O points.
14. Maintaining, calibrating, troubleshooting, diagnosing and repairing hardware.
15. Adjusting, calibrating and replacing DDC system components.
16. <**Insert requirement**>.

O. Training Content for System Managers and Administrators:

Subparagraphs below are examples only and must be revised to suit Project.

1. DDC system software maintenance and backups.
2. Uploading, downloading and off-line archiving of all DDC system software and databases.

3. Interface with Project-specific, third-party operator software.
4. Understanding password and security procedures.
5. Adding new operators and making modifications to existing operators.
6. Operator password assignments and modification.
7. Operator authority assignment and modification.
8. Workstation data segregation and modification.
9. <**Insert requirement**>.

P. Video of Training Sessions:

1. Provide a digital video and audio recording of each training session. Create a separate recording file for each session.
2. Stamp each recording file with training session number, session name and date.
3. Provide Owner with [**two**] <**Insert number**> copies of digital files on DVDs or flash drives for later reference and for use in future training.
4. Owner retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION 230923

SECTION 230923.11 - CONTROL VALVES

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes control valves and actuators for DDC systems.

B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 230923 "Direct Digital Control (DDC) System for HVAC" control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
2. Section 230993.11 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.11.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. Cv: Design valve coefficient.

B. DDC: Direct-digital control.

C. NBR: Nitrile butadiene rubber.

D. PTFE: Polytetrafluoroethylene

E. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product, including the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation, operation, and maintenance instructions, including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and[**mounting**] details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include diagrams for pneumatic signal and main air tubing.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

C. Delegated-Design Submittal:

1. Schedule and design calculations for control valves and actuators, including the following:

   a. Flow at project design and minimum flow conditions.
   b. Pressure differential drop across valve at project design flow condition.
   c. Maximum system pressure differential drop (pump close-off pressure) across valve at project minimum flow condition.
   d. Design and minimum control valve coefficient with corresponding valve position.
   e. Maximum close-off pressure.
   f. Leakage flow at maximum system pressure differential.
   g. Torque required at worst case condition for sizing actuator.
   h. Actuator selection indicating torque provided.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

   1. Control valve installation location shown in relationship to room, duct, pipe, and equipment.
   2. Size and location of wall access panels for control valves installed behind walls.
   3. Size and location of ceiling access panels for control valves installed above inaccessible ceilings.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For control valves to include in operation and maintenance manuals.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASME Compliance: Fabricate and label products to comply with ASME Boiler and Pressure Vessel Code where required by authorities having jurisdiction.

Retain "Delegated Design" Paragraph below if Contractor is required to assume responsibility for design.

C. Delegated Design: Engage a qualified professional[**engineer**], as defined in Section 014000 "Quality Requirements," to size products where indicated as delegated design.

D. Ground Fault: Products shall not fail due to ground fault condition when suitably grounded.

E. Backup Power Source: Systems and equipment served by a backup power source shall have associated control valve actuators served from a backup power source.

F. Environmental Conditions:

1. Provide electric control valve actuators, with protective enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Electric control valve actuators not available with integral enclosures, complying with requirements indicated, shall be housed in protective secondary enclosures.

a. Hazardous Locations: Explosion-proof rating for condition.

G. Determine control valve sizes and flow coefficients by ISA 75.01.01.

H. Control valve characteristics and rangeability shall comply with ISA 75.11.01.

I. Selection Criteria:

1. Control valves shall be suitable for operation at following conditions:

a. Chilled Water: <**Insert pressure and coincident temperature requirements**>.
b. Condenser Water: <**Insert pressure and coincident temperature requirements**>.
c. Heat Recovery: <**Insert pressure and coincident temperature requirements**>.
d. Heating Hot Water: <**Insert pressure and coincident temperature requirements**>.
e. Steam: <**Insert pressure and coincident temperature requirements**>.
f. <**Insert system and requirements**>.

2. Control valve shutoff classifications shall be FCI 70-2, Class IV or better unless otherwise indicated.
3. Valve pattern, three-way or straight through, shall be as indicated on Drawings.
4. Modulating straight-through pattern control valves shall have equal percentage flow-throttling characteristics unless otherwise indicated.
5. Modulating three-way pattern water valves shall have linear flow-throttling characteristics. The total flow through the valve shall remain constant regardless of the valve's position.
6. Modulating butterfly valves shall have [**linear**] [**or**] [**equal percentage**] flow-throttling characteristics.

Retain first subparagraph below to define fail positions unless otherwise indicated.

7. Fail positions unless otherwise indicated:

   a. Chilled Water: [**Close**] [**Last position**] [**Open**].
   b. Condenser Water: [**Close**] [**Last position**] [**Open**].
   c. Heat Recovery: [**Close**] [**Last position**] [**Open**].
   d. Heating Hot Water: [**Close**] [**Last position**] [**Open**].
   e. Steam: [**Close**] [**Last position**] [**Open**].
   f. <**Insert system and fail position**>.

8. Globe-type control valves shall pass the design flow required with not more than 95 percent of stem lift unless otherwise indicated.
9. Rotary-type control valves, such as ball and butterfly valves, shall have Cv falling between 65 and 75 degrees of valve full open position and minimum valve Cv between 15 and 25 percent of open position.
10. Selection shall consider viscosity, flashing, and cavitation corrections.
11. Valves shall have stable operation throughout full range of operation, from design to minimum Cv.
12. Minimum Cv shall be calculated at [**10**] <**Insert number**> percent of design flow, with a coincident pressure differential equal to the system design pump head.
13. In water systems, select modulating control valves at terminal equipment for a design Cv based on a pressure drop of [**5 psig**] [**7 psig**] <**Insert value**> at design flow unless otherwise indicated.
14. Modulating valve sizes for steam service shall provide a pressure drop at design flow equal to lesser of the following:

   a. [**50**] <**Insert number**> percent of the valve inlet pressure.
   b. [**50**] <**Insert number**> percent of the absolute steam pressure at the valve inlet.

15. Two-position control valves shall be line size unless otherwise indicated.
16. In water systems, use ball- or globe-style control valves for two-position control for valves NPS 2 and smaller and butterfly style for valves larger than NPS 2.
17. In steam systems, use ball- or globe-style control valves regardless of size.

Retain two subparagraphs below for pneumatic control valves with special installation requirements.

18. Pneumatic, two-position control valves shall provide a smooth opening and closing characteristic slow enough to avoid water hammer. Valves with pneumatic actuators shall have an adjustable opening time (valve full closed to full open) and an adjustable closing time (valve full open to full closed) ranging from zero to 10 seconds. Opening and closing times shall be independently adjustable.
19. Control valve, pneumatic-control signal shall not exceed 200 feet. For longer distances, provide an electric/electronic control signal to the valve and an electric solenoid valve or electro-pneumatic transducer at the valve to convert the control signal to pneumatic.

2.2 BALL-STYLE CONTROL VALVES

A. Ball Valves with Single Port and Characterized Disk:

   1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Belimo's "B2 series."

2. Pressure Rating for NPS 1 and Smaller: Nominal 600 WOG.
3. Pressure Rating for NPS 1-1/2 through NPS 2: Nominal 400 WOG.
4. Close-off Pressure: 200 psig.
5. Process Temperature Range: Zero to 212 deg F.
6. Body and Tail Piece: Cast bronze ASTM B61, ASTM B62, ASTM B584, or forged brass with nickel plating.
7. End Connections: Threaded (NPT) ends.
8. Ball: [**Chrome-plated brass or bronze**] [**or**] [**300 series stainless steel**].
9. Stem and Stem Extension:

   a. Material to match ball.
   b. Blowout-proof design.
   c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.

10. Ball Seats: Reinforced PTFE.
11. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
12. Flow Characteristic: Equal percentage.

B. Ball Valves with Two Ports and Characterized Disk:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Belimo's "B3 series."

2. Pressure Rating for NPS 1 and Smaller: Nominal 600 WOG.
3. Pressure Rating for NPS 1-1/2 through NPS 2: Nominal 400 WOG.
4. Close-off Pressure: 200 psig.
5. Process Temperature Range: Zero to 212 deg F.
6. Body and Tail Piece: Cast bronze ASTM B61, ASTM B62, ASTM B584, or forged brass with nickel plating.
7. End Connections: Threaded (NPT) ends.
8. Ball: [**Chrome-plated brass or bronze**] [**or**] [**300 series stainless steel**].
9. Stem and Stem Extension:

   a. Material to match ball.
   b. Blowout-proof design.
   c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.

10. Ball Seats: Reinforced PTFE.
11. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
12. Flow Characteristics for A-Port: Equal percentage.
13. Flow Characteristics for B-Port: Modified for constant common port flow.

C. Ball Valves with Single Port and Segmented Ball:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Valve Solutions' "V series."

2. Performance:

    a. Process Temperature Rating: Minus 20 to plus 450 deg F.
    b. ASME B16.34, [**Class 150**] [**or**] [**Class 300**].
    c. Leakage: FCI 70-2, Class IV.
    d. Rangeability: 300 to 1.
    e. Rotation: Zero to 90 degrees.
    f. Equal percentage flow characteristic.

3. ASME B16.10 face-to-face dimensions.
4. Valves NPS 2 and Smaller: Threaded (NPT) ends.
5. Valves NPS 2-1/2 through NPS 6: Flanged ends suitable for mating to ASME B16.5 flanges.
6. Body: [**Carbon**] [**or**] [**stainless**] steel.
7. Ball and Shaft: Stainless steel.
8. Shaft and Segmented Ball: Pinned and welded.
9. Ball Seat: Graphite.
10. Packing: PTFE V-rings and graphite packing follower.
11. Replaceable seat, ball, and shaft packing.
12. Label each valve with following:

    a. Manufacturer's name, model number, and serial number.
    b. Body size.
    c. Flow directional arrow.

D. Ball Valves with Segmented Ball, Three-Way Pattern:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Valve Solutions' "V series."

2. Arrangement: Two single-port valves mated to a fabricated tee with interconnecting mechanical linkage.
3. Performance:

    a. Process Temperature Rating: Minus 20 to plus 450 deg F.
    b. ASME B16.34, [**Class 150**] [**or**] [**Class 300**].
    c. Leakage: FCI 70-2, Class IV.
    d. Rangeability: 300 to 1.
    e. Rotation: Zero to 90 degrees.
    f. Equal percentage flow characteristic.

4. Face-to-Face Dimensions: ASME B16.10.
5. Valves NPS 3 through NPS 6: Flanged ends suitable for mating to ASME B16.5 flanges.
6. Body: [**Carbon**] [**or**] [**stainless**] steel.
7. Ball and Shaft: Stainless steel.
8. Shaft and Segmented Ball: Pinned and welded.
9. Ball Seat: Graphite.
10. Packing: PTFE V-rings and graphite packing follower.

11. Replaceable seat, ball, and shaft packing.
12. Label each valve with following:

    a. Manufacturer's name, model number, and serial number.
    b. Body size.
    c. Flow directional arrow.

E. Ball Valves with Full Ball and Characterized V-Notch:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Flow-Tek's "Triad and F series."

2. Performance:

    a. Process Temperature Rating: Minus 20 to plus 500 deg F.
    b. ASME B16.34, Class 600 for NPS 2 and smaller; [**Class 150**] [**or**] [**Class 300**] for larger than NPS 2.
    c. Leakage: FCI 70-2, Class VI, bi-directional.
    d. Rangeability: Varies from 200 to 1 up to 800 to 1 based on notch pattern of ball.
    e. Rotation: Zero to 90 degrees.
    f. Equal percentage flow characteristic.
    g. Full port.

3. Face-to-Face Dimension: ASME B16.10 long pattern.
4. Valves NPS 2 and Smaller: ASME B1.20.1 threaded (NPT) ends and three-piece body.
5. Valves NPS 2-1/2 through NPS 12: Flanged ends suitable for mating to ASME B16.5 flanges and two-piece body.
6. Hole in the stem slot of each ball equalizes pressure between the body cavity and the line media flow.
7. Replaceable seat, ball, and shaft packing.
8. Body: [**Carbon**] [**or**] [**stainless**] steel.
9. Ball and Shaft: Stainless steel.
10. Ball Seat: RPTFE.
11. Stem Seals for Valves NPS 2 and Smaller: Live-loaded, self-adjusting, primary and secondary sealing using belleville washers.

    a. Primary Seal: Combination of thrust washer and thrust washer protector.
    b. Secondary Seal: Adjustable stem packing composed of RPTFE V-rings.

12. Stem Seals for Valves Larger than NPS 2: Independent packing gland, adjusted without removing mounting hardware or operator, and contoured to uniformly distribute load across packing.

    a. Primary Seal: Combination of thrust washer and thrust washer protector.
    b. Secondary Seal: Adjustable stem packing composed of RPTFE V-rings.

13. Label each valve with following:

    a. Manufacturer's name, model number, and serial number.
    b. Body size.
    c. Flow directional arrow.

F. Industrial-Grade Ball Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Fisher's "V150 or V300 series."

2. Performance:

   a. Process Temperature Rating: Minus 20 to plus 450 deg F.
   b. ASME B16.34, [**Class 150**] [**or**] [**Class 300**].
   c. Leakage: FCI 70-2, Class VI.
   d. Rangeability: 300 to 1.
   e. Rotation: Zero to 90 degrees.
   f. Modified equal percentage flow characteristic.

3. Face-to-Face Dimensions: Comply with ASME B16.10 short pattern.
4. Body: Cast steel ASTM A216/A216M WCB.
5. Flanged Body: Suitable for mating to ASME B16.5 flanges.
6. Shaft: 316 stainless-steel ball, 17-4 PH stainless steel.
7. Ball Seat: Reinforced PTFE.
8. PTFE V-ring packing, 316 stainless-steel packing follower.
9. Replaceable seat, ball, and shaft packings.
10. Replaceable 316 stainless-steel shaft bushings with PTFE linings.
11. Corrosion-resistant nameplate indicating the following:

   a. Manufacturer's name, model number, and serial number.
   b. Body size.
   c. Body and trim materials.
   d. Trim type.
   e. Body and flange rating.
   f. Arrow indicating direction of flow.

G. Pressure-Independent Ball Valves NPS 2 and Smaller:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Belimo's "PICCV series."

2. Performance:

   a. Pressure Rating: 600 psig for NPS 1 and 400 psig for NPS 1-1/2 and NPS 2.
   b. Close-off pressure of 200 psig.
   c. Process Temperature Range: Between zero to 212 deg F.
   d. Rangeability: 100 to 1.

3. Integral Pressure Regulator: Located upstream of ball to regulate pressure, to maintain a constant pressure differential while operating within a pressure differential range of 5 to 50 psig.
4. Body: Forged brass, nickel plated, and with threaded ends.
5. Ball: Chrome-plated brass.
6. Stem and Stem Extension: Chrome-plated brass, blowout-proof design.
7. Stem sleeve or other approved means to allow valve to be opened and closed without damaging field-applied insulation and insulation vapor barrier seal.

8. Ball Seats: Reinforced PTFE.
9. Stem Seal: Reinforced PTFE packing ring stem seal with threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if equivalent cycle endurance can be achieved.
10. Flow Characteristic: Equal percentage.

2.3 BUTTERFLY-STYLE CONTROL VALVES

A. Commercial-Grade, Two-Way Butterfly Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Keystone's "Figure 222 series."

2. Performance:
    a. Bi-directional bubble tight shutoff at 250 psig.
    b. Comply with MSS SP-67 or MSS SP-68.
    c. Rotation: Zero to 90 degrees.
    d. Linear or modified equal percentage flow characteristic.
3. Body: Cast iron ASTM A126, Class B, ductile iron ASTM A536 or cast steel ASTM A216/A216M WCB fully lugged, suitable for mating to ASME B16.5 flanges.
4. Disc: 316 stainless steel.
5. Shaft: 316 or 17-4 PH stainless steel.
6. Seat: Reinforced EPDM or reinforced PTFE with retaining ring.
7. Shaft Bushings: Reinforced PTFE or stainless steel.
8. Replaceable seat, disc, and shaft bushings.
9. Corrosion-resistant nameplate indicating:
    a. Manufacturer's name, model number, and serial number.
    b. Body size.
    c. Body and trim materials.
    d. Flow arrow.

B. Commercial-Grade, Three-Way Butterfly Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Keystone's "Figure 222 series."

2. Arrangement: Two valves mated to a fabricated tee with interconnecting mechanical linkage.
3. Performance:
    a. Bi-directional bubble tight shutoff at 250 psig.
    b. Comply with MSS SP-67 or MSS SP-68.
    c. Rotation: Zero to 90 degrees.
    d. Linear or modified equal percentage flow characteristic.

4. Body: Cast iron ASTM A126, Class B, ductile iron ASTM A536 or cast steel ASTM A216/A216M WCB fully lugged, suitable for mating to ASME B16.5 flanges.
5. Disc: 316 stainless steel.
6. Shaft: 316 or 17-4 PH stainless steel.
7. Seat: Reinforced EPDM or reinforced PTFE seat with retaining ring.
8. Shaft Bushings: Reinforced PTFE or stainless steel.
9. Replaceable seat, disc, and shaft bushings.
10. Corrosion-resistant nameplate indicating:

    a. Manufacturer's name, model number, and serial number.
    b. Body size.
    c. Body and trim materials.
    d. Flow arrow.

C. Industrial-Grade Butterfly Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Fisher's "8532 and 8580 series."

2. Performance:

    a. Process Temperature Rating: Minus 200 to plus 849 deg F.
    b. ASME B16.34, [**Class 150**] [**or**] [**Class 300**] for larger sizes.
    c. Complies with MSS SP-68.
    d. Leakage: FCI 70-2, Class VI, bi-directional.
    e. Rangeability: 100 to 1.
    f. Rotation: Zero to 90 degrees.
    g. Linear or modified equal percentage flow characteristic.

3. Body: Cast steel ASTM A216/A216M WCB, fully lugged, suitable for mating to ASME B16.5 flanges.
4. Disc: ASTM A351/A351M, CF3M or CF8M stainless steel.
5. Shaft: 17-4 PH stainless steel.
6. Seat: Reinforced PTFE with retaining ring.
7. Shaft Bushings: Reinforced PTFE or stainless steel.
8. Replaceable seat, disc, and shaft bushings.
9. Corrosion-resistant nameplate indicating:

    a. Manufacturer's name, model number, and serial number.
    b. Body size.
    c. Body and trim materials.
    d. Body rating.
    e. Arrow indicating direction of flow.

2.4 GLOBE-STYLE CONTROL VALVES

A. General Globe-Style Valve Requirements:

1. Globe-style control valve body dimensions shall comply with ISA 75.08.01.
2. Construct the valves to be serviceable from the top.

3. For cage guided valves, trim shall be field interchangeable for different valve flow characteristics, such as equal percentage, linear, and quick opening.
4. Reduced trim for one nominal size smaller shall be available for industrial valves NPS 1 and larger.
5. Replaceable seats and plugs.
6. Furnish each control valve with a corrosion-resistant nameplate indicating the following:

    a. Manufacturer's name, model number, and serial number.
    b. Body and trim size.
    c. Arrow indicating direction of flow.

B. Two-Way Globe Valves NPS 2 and Smaller:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Johnson's "VG7000 series."

2. Globe Style: Single port.
3. Body: Cast bronze or forged brass with ASME B16.5, Class 250 rating.
4. End Connections: Threaded.
5. Bonnet: Screwed.
6. Packing: PTFE V-ring.
7. Plug: Top guided.
8. Plug, Seat, and Stem: [**Brass**] [**or**] [**stainless steel**].
9. Process Temperature Range: 35 to 248 deg F.
10. Ambient Operating Temperature: 35 to 150 deg F.
11. Leakage: FCI 70-2, Class IV.
12. Rangeability: 25 to 1.
13. Equal percentage flow characteristic.

C. Three-Way Globe Valves NPS 2 and Smaller:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Johnson's "VG7000 series."

2. Globe Style: Mix flow pattern.
3. Body: Cast bronze or forged brass with ASME B16.5, Class 250 rating.
4. End Connections: Threaded.
5. Bonnet: Screwed.
6. Packing: PTFE V-ring.
7. Plug: Top guided.
8. Plug, Seat, and Stem: [**Brass**] [**or**] [**stainless steel**].
9. Process Temperature Range: 35 to 248 deg F.
10. Ambient Operating Temperature: 35 to 150 deg F.
11. Leakage: FCI 70-2, Class IV.
12. Rangeability: 25 to 1.
13. Linear flow characteristic.

D. Two-Way Globe Valves NPS 2-1/2 to NPS 6:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Johnson's "VG2000 series."

2. Globe Style: Single port.
3. Body: Cast iron complying with ASME B61.1, Class 125.
4. End Connections: Flanged, suitable for mating to ASME B16.5, Class 150 flanges.
5. Bonnet: Bolted.
6. Packing: PTFE cone-ring.
7. Plug: Top or bottom guided.
8. Plug, Seat, and Stem: Brass or stainless steel.
9. Process Temperature Rating: 35 to 281 deg F.
10. Leakage: 0.1 percent of maximum flow.
11. Rangeability: Varies with valve size between 6 and 10 to 1.
12. Modified linear flow characteristic.

E. Three-Way Globe Valves NPS 2-1/2 to NPS 6:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Johnson's "VG2000 series."

2. Globe Style: Mix flow pattern.
3. Body: Cast iron complying with ASME B61.1, Class 125.
4. End Connections: Flanged suitable for mating to ASME B16.5, Class 150 flanges.
5. Bonnet: Bolted.
6. Packing: PTFE cone-ring.
7. Plug: Top or bottom guided.
8. Plug, Seat, and Stem: Brass or stainless steel.
9. Process Temperature Rating: 35 to 281 deg F.
10. Leakage: 0.1 percent of maximum flow.
11. Rangeability: Varies with valve size between 6 and 10 to 1.
12. Modified linear flow characteristic.

F. Industrial-Grade Straight-Through Globe Valves NPS 3/4 and Smaller:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Fisher's "24000 series."

2. Globe Style: Single port.
3. Body: ASTM B62 bronze complying with ASME B16.5, Class 250.
4. End Connections: Threaded.
5. Bonnet: Screwed or bolted.
6. Packing: PTFE V-ring.
7. Plug: Top or cage guided; balanced or unbalanced.
8. Plug, Seat, and Stem: 316 stainless steel, 17-4 PH stainless-steel cage.
9. Process Temperature Range: Minus 20 to plus 400 deg F.
10. Ambient Operating Temperature: Minus 20 to plus 150 deg F.
11. Leakage: FCI 70-2, Class IV.
12. Equal percentage flow characteristic.

G. Industrial-Grade Straight-Through Globe Valves NPS 1 and Larger:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Subparagraphs below are based on Fisher's "ET series."

2. Globe Style: Single port.
3. Body: Cast iron or cast steel.
4. End Connections for NPS 2: Threaded.
5. End Connections for NPS 2-1/2 and Larger: Raised face flanged.
6. Bonnet: Bolted.
7. Packing: PTFE V-ring.
8. Plug: Cage guided and unbalanced.
9. Plug, Seat, and Stem: 416 stainless-steel plug and seat, 17-4 PH stainless-steel cage and 316 stainless-steel stem.
10. Valve Stem: Thread and pin stem to plug.
11. Valve Stem Finish: Polished to 5 microinches rms or less.
12. Plug and Seat Surfaces: Hardened facing.
13. Process Temperature Range: Zero to 450 deg F.
14. Ambient Operating Temperature: Minus 20 to plus 150 deg F.
15. Leakage: FCI 70-2, [**Class IV**] [**Class V**] [**Class VI**].
16. Flow Characteristic: [**Equal percentage**] [**Linear**] [**Quick opening**].

2.5 SOLENOID VALVES

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Description:

Subparagraphs below are based on ASCO's "8210 series."

1. Action: Either normally open or normally closed in the event of electrical power failure as required by the application.
2. Size to close against the system pressure.
3. Manual override capable.
4. Heavy-duty assembly.
5. Body: [**Brass**] [**or**] [**stainless steel**].
6. Seats and Discs: NBR or PTFE.
7. Solenoid Enclosure: NEMA 250, Type 4.

2.6 SELF-CONTAINED TEMPERATURE REGULATING VALVE

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Description:

Subparagraphs below are based on Jordan's "Mark 80 series."

1. Self-contained and self-operated temperature regulating valve. Direct acting or reverse acting as required by application.
2. Direct Acting: A rise in temperature at the sensing bulb vaporizes some of the liquid in the bulb, forcing the remaining liquid through a capillary to apply pressure at the diaphragm, in turn closing the valve. The valve shall fail open.

3. Reverse Acting: A rise in temperature at the sensing bulb vaporizes some of the liquid in the bulb, forcing the remaining liquid through a capillary to apply pressure at the diaphragm, in turn opening the valve. The valve shall fail close.
4. Body: Carbon steel.
5. Trim and Seats: 300 series stainless steel.
6. Yoke: Cast iron.
7. Actuator: 300 series stainless steel.
8. End Connections: Threaded.
9. Capillary, Bulb, and Armor: 300 series stainless steel.
10. Thermal Fill Material: Match to the temperature range.
11. Thermowell: Type 316 stainless-steel thermowell sized to fit the bulb and pipe.

C. Operational Characteristics: Control flow from between 5 to 100 percent of rated capacity.

D. Interchangeable trim for one size smaller.

E. Valve Leakage: Comply with FCI 70-2, Class IV.

F. Temperature Range: Match application.

1. Drains from Hot Equipment to Sanitary Sewer System: 105 to 165 deg F.
2. <**Insert description of applications**>.

G. Valve Size: Size to pass the design flow required with not more than 95 percent of the stem lift while operating at design pressure.

2.7 PNEUMATIC CONTROL VALVE ACTUATORS

A. Actuators for Hydronic Control Valves: Shutoff against system pump shutoff head.

B. Actuators for Steam Control Valves: Shutoff against [**1.2**] [**1.5**] <**Insert number**> times steam design pressure.

C. Position indicator and graduated scale on each actuator.

D. Provide diaphragm action (air-to-open, air-to-close), as required by the sequence of operation, in the event of air supply failure.

E. For each modulating control valve, provide a positive positioner with the valve actuator. The positioners shall operate on a 3- to 15-psig input signal unless otherwise required to satisfy control sequences of operation. Integrally mount each positioner with an air regulator, air set, and gauges for supply, input and output. The positioner shall have the following performance characteristics:

1. Linearity: Plus or minus 1 percent of the output signal span.
2. Hysteresis: 0.5 percent of span.

F. Diaphragms shall be replaceable.

G. Actuator Construction:

1. Cast-iron or steel diaphragm casing and plate. Cast aluminum is acceptable on valves NPS 4 and smaller.
2. Cast iron or steel yoke. Cast aluminum is acceptable on valves NPS 4 and smaller.
3. Reinforced synthetic rubber or nitrile diaphragm.
4. Steel or steel alloy spring, stem, and spring adjuster.

H. Rate actuators for not less than 1.2 times the main air pressure to the valve, minimum 30 psig.

2.8 ELECTRIC AND ELECTRONIC CONTROL VALVE ACTUATORS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Actuators for Hydronic Control Valves: Capable of closing valve against system pump shutoff head.

C. Actuators for Steam Control Valves: Shutoff against [**1.2**] [**1.5**] <**Insert number**> times steam design pressure.

D. Position indicator and graduated scale on each actuator.

E. Type: Motor operated, with or without gears, electric and electronic.

F. Voltage: [**Voltage selection delegated to professional designing control system**] [**24-V ac**] [**120-V ac**] <**Insert requirement**>.

G. Deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.

H. Function properly within a range of 85 to 120 percent of nameplate voltage.

I. Construction:

1. For Actuators Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
2. For Actuators from 100 to 400 W: Gears ground steel, oil immersed, shaft hardened steel running in bronze, copper alloy or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel or cast-aluminum housing.
3. For Actuators Larger Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.

J. Field Adjustment:

1. Spring Return Actuators: Easily switchable from fail open to fail closed in the field without replacement.
2. Gear Type Actuators: External manual adjustment mechanism to allow manual positioning when the actuator is not powered.

K. Two-Position Actuators: Single direction, spring return or reversing type.

L. Modulating Actuators:

1. Operation: Capable of stopping at all points across full range, and starting in either direction from any point in range.
2. Control Input Signal:

Retain subparagraphs below that remain after revising "Control Valve Applications" Article. See "Control Signal Options" discussion in Evaluations.

a. Three Point, Tristate, or Floating Point: Clockwise and counter-clockwise inputs. One input drives actuator to open position and other input drives actuator to close position. No signal of either input remains in last position.
b. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for [**zero- to 10-**] [**or**] [**2- to 10-**]V dc [**and**] [**4- to 20-mA**] signals.
c. Pulse Width Modulation (PWM): Actuator drives to a specified position according to pulse duration (length) of signal from a dry contact closure, triac sink, or source controller.

Retaining "Programmable Multi-Function" Subparagraph below limits manufacturer choices. Belimo is most well-known manufacturer offering product.

d. Programmable Multi-Function:

1) Control Input, Position Feedback, and Running Time: Factory or field programmable.
2) Diagnostic: Feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
3) Service Data: Include, at a minimum, number of hours powered and number of hours in motion.

M. Position Feedback:

Retain one of first two subparagraphs below to provide a signal for remote monitoring of position through positive means. Remote monitoring requires additional control inputs. Coordinate requirements with interface to control system.

1. [**Equip**] [**Where indicated, equip**] two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of [**open**] [**and**] [**close**] position.
2. [**Equip**] [**Where indicated, equip**] modulating actuators with a position feedback through [**current**] [**or**] [**voltage**] signal for remote monitoring.
3. Provide a position indicator and graduated scale on each actuator indicating open and closed travel limits.

N. Fail-Safe:

1. Where indicated, provide actuator to fail to an end position.
2. Internal spring return mechanism to drive controlled device to an end position (open or close) on loss of power.
3. Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.

O. Integral Overload Protection:

1. Provide against overload throughout the entire operating range in both directions.
2. Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.

P. Valve Attachment:

1. Unless otherwise required for valve interface, provide an actuator designed to be directly coupled to valve shaft without the need for connecting linkages.
2. Attach actuator to valve drive shaft in a way that ensures maximum transfer of power and torque without slippage.
3. Bolt and set screw method of attachment is acceptable only if provided with at least two points of attachment.

Q. Temperature and Humidity:

1. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of [**minus 20 to plus 120 deg F**] <**Insert temperature range**>.
2. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from [**5 to 95**] <**Insert number(s)**> percent relative humidity, non-condensing.

R. Enclosure:

1. Suitable for ambient conditions encountered by application.
2. NEMA 250, Type 2 for indoor and protected applications.
3. NEMA 250, Type 4 or Type 4X for outdoor and unprotected applications.
4. Provide actuator enclosure with heater and control where required by application.

S. Stroke Time:

1. Operate valve from fully closed to fully open within [**15**] [**60**] [**75**] [**90**] [**150**] <**Insert number**> seconds.
2. Operate valve from fully open to fully closed within [**15**] [**60**] [**75**] [**90**] [**150**] <**Insert number**> seconds.
3. Move valve to failed position within [**5**] [**15**] [**30**] <**Insert number**> seconds.
4. Select operating speed to be compatible with equipment and system operation.

T. Sound:

1. Spring Return: [**62**] <**Insert number**> dBA.
2. Non-Spring Return: [**45**] <**Insert number**> dBA.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for valves installed in piping to verify actual locations of piping connections before installation.

C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CONTROL VALVE APPLICATIONS

Retain this article unless all requirements for control devices for different applications are indicated on Drawings. Where Drawings indicate only some requirements, revise article accordingly.

Delete article if instrument types are indicated on Drawings.

A. Control Valves:

Retain first subparagraph below and delete second if selection of instrument types is delegated to Contractor.

1. Select from valves specified in "Control Valves" Article to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.

Copy and revise subparagraphs below to suit each system and unique application requiring a different control valve type. Where "(Insert system)" is indicated, insert system type: "Chilled-, "Condenser-, "Heat-Recovery-, or "Hot-Water." Where "(Insert unique application)" is indicated, insert unique requirement, such as equipment class, or if common to all, insert "General."

2. <**Insert system**> System, <**Insert unique application**>, Two-Way Applications Controlled by Flow: [**Ball valves with single port and characterized disk**] [**Ball valves with single port and segmented ball**] [**Ball valves with full ball and characterized V-notch**] [**Industrial-grade ball valves**] [**Pressure-independent ball valves**] [**Butterfly-style valves, commercial-grade, two-way valves**] [**Butterfly-style valves, industrial-grade valves**] [**Globe-style, two-way valves**] [**Globe-style, industrial-grade, straight-through valves**].
3. <**Insert system**> System, <**Insert unique application**>,Two-Way Applications Controlled by Pressure: [**Ball valves with single port and characterized disk**] [**Ball valves with single port and segmented ball**] [**Ball valves with full ball and characterized V-notch**] [**Industrial-grade ball valves**] [**Pressure-independent ball valves**] [**Butterfly-style valves, commercial-grade, two-way valves**] [**Butterfly-style valves, industrial-grade valves**] [**Globe-style, two-way valves**] [**Globe-style, industrial-grade, straight-through valves**].
4. <**Insert system**> System, <**Insert unique application**>, Two-Way Applications Controlled by Temperature: [**Ball valves with single port and characterized disk**] [**Ball valves with single port and segmented ball**] [**Ball valves with full ball and characterized V-notch**] [**Industrial-grade ball valves**] [**Pressure-independent ball valves**] [**Butterfly-style valves, commercial-grade, two-way valves**] [**Butterfly-style valves, industrial-grade valves**] [**Globe-style, two-way valves**] [**Globe-style, industrial-grade, straight-through valves**] [**Solenoid valves**] [**Self-contained temperature regulating valves**].

5. <**Insert system**> System, <**Insert unique application**>, Three Way, Controlled by Temperature: [**Ball valves with two ports and characterized disk**] [**Ball valves with segmented ball, three-way pattern**] [**Butterfly-style valves, commercial-grade, three-way valves**] [**Globe-style, three-way valves**].
6. Steam System, <**Insert unique application**>, Two Way, Controlled by Temperature: [**Ball valves with single port and segmented ball**] [**Ball valves with full ball and characterized V-notch**] [**Industrial-grade ball valves**] [**Globe-style, two-way valves**] [**Globe-style, industrial-grade, straight-through valves**].

3.3 INSTALLATION, GENERAL

A. Furnish and install products required to satisfy most stringent requirements indicated.

B. Install products level, plumb, parallel, and perpendicular with building construction.

C. Properly support instruments, tubing, piping, wiring, and conduits to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a <**Insert value**> force.

D. Provide ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.

E. Firestop penetrations made in fire-rated assemblies and seal penetrations made in acoustically rated assemblies.

F. Fastening Hardware:

1. Stillson wrenches, pliers, and other tools that will cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for assembling and tightening nuts.
2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.

G. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.

H. Corrosive Environments:

1. Use products that are suitable for environment to which they will be subjected.
2. If possible, avoid or limit use of materials in corrosive environments, including. but not limited to, the following:

   a. Laboratory exhaust airstreams.
   b. Process exhaust airstreams.

3. Use Type 316 stainless-steel tubing and fittings when in contact with a corrosive environment.

4. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
5. Where control devices are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

A. Furnish and install electrical power to products requiring electrical connections.

B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."

C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 CONTROL VALVES

A. Install pipe reducers for valves smaller than line size. Position reducers as close to valve as possible but at distance to avoid interference and impact to performance. Install with manufacturer-recommended clearance.

B. Install flanges or unions to allow drop-in and -out valve installation.

Retain first paragraph below for critical applications requiring uninterrupted flow. Indicate locations on Drawings or by defining requirements in subparagraph below.

C. Where indicated, install control valve with three-valve bypass manifold to allow for control valve isolation and removal without interrupting system flow by providing manual throttling valve in bypass pipe.

1. <**Insert applications**>.

D. Install drain valves in piping upstream and downstream of each control valve installed in a three-valve manifold and for each control valve larger than [**NPS 2**] [**NPS 4**] <**Insert nominal pipe size**>.

E. Install pressure temperature taps in piping upstream and downstream of each control valve larger than [**NPS 1**] [**NPS 2**] <**Insert nominal pipe size**>.

F. Valve Orientation:

1. Where possible, install globe and ball valves installed in horizontal piping with stems upright and not more than 15 degrees off of vertical, not inverted.
2. Install valves in a position to allow full stem movement.

3. Where possible, install butterfly valves that are installed in horizontal piping with stems in horizontal position and with low point of disc opening with direction of flow.

G. Clearance:

1. Locate valves for easy access and provide separate support of valves that cannot be handled by service personnel without hoisting mechanism.
2. Install valves with at least 12 inches of clear space around valve and between valves and adjacent surfaces.

H. Threaded Valves:

1. Note internal length of threads in valve ends, and proximity of valve internal seat or wall, to determine how far pipe should be threaded into valve.
2. Align threads at point of assembly.
3. Apply thread compound to external pipe threads, except where dry seal threading is specified.
4. Assemble joint, wrench tight. Apply wrench on valve end as pipe is being threaded.

I. Flanged Valves:

1. Align flange surfaces parallel.
2. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets as flat and parallel as possible. Use suitable lubricants on bolt threads. Tighten bolts gradually and uniformly with a torque wrench.

3.6 CONNECTIONS

A. Connect electrical devices and components to electrical grounding system. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

B. Install engraved phenolic nameplate with valve identification on valve[**and on face of ceiling directly below valves concealed above ceilings**].

3.8 CLEANING

A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.

B. Wash and shine glazing.

C. Polish glossy surfaces to a clean shine.

3.9 CHECKOUT PROCEDURES

A. Control Valve Checkout:

1. Check installed products before continuity tests, leak tests, and calibration.
2. Check valves for proper location and accessibility.
3. Check valves for proper installation for direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
4. For pneumatic products, verify air supply for each product is properly installed.
5. For pneumatic valves, verify that pressure gauges are provided in each air line to valve actuator and positioner.
6. Verify that control valves are installed correctly for flow direction.
7. Verify that valve body attachment is properly secured and sealed.
8. Verify that valve actuator and linkage attachment are secure.
9. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
10. Verify that valve ball, disc, and plug travel are unobstructed.
11. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.

3.10 ADJUSTMENT, CALIBRATION, AND TESTING

A. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed back to 100 percent open.

B. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed, and 100 percent open at proper air pressures.

C. Check and document open and close cycle times for applications with a cycle time of less than 30 seconds.

D. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

END OF SECTION 230923.11

SECTION 232113 - HYDRONIC PIPING

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer's products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes pipe and fitting materials and joining methods for the following:

1. Copper tube and fittings.
2. Steel pipe and fittings.
3. Plastic pipe and fittings.
4. Fiberglass pipe and fittings.
5. Joining materials.
6. Transition fittings.

7. Dielectric fittings.
8. Bypass chemical feeder.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of the following:

1. Pipe.
2. Fittings.
3. Joining materials.
4. Bypass chemical feeder.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for adhesives.>
2. <Double click to insert sustainable design text for EPDs and HPDs.>

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

C. Delegated-Design Submittal:

1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion joints and loops, and attachments of the same to the building structure.
2. Locations of pipe anchors and alignment guides and expansion joints and loops.
3. Locations of and details for penetrations, including sleeves and sleeve seals for exterior walls, floors, basement, and foundation walls.
4. Locations of and details for penetration and firestopping for fire- and smoke-rated wall and floor and ceiling assemblies.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Suspended ceiling components.
2. Other building services.
3. Structural members.

Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as may be supplemented in "Quality Assurance" Article.

B. Qualification Data: For Installer.

Retain "Welding certificates" Paragraph below if retaining "Steel Support Welding" or "Pipe Welding" Paragraph in "Quality Assurance" Article.

C. Welding certificates.

D. Field quality-control reports.

Retain "Preconstruction Test Reports" Paragraph below if specifying preconstruction testing in "Preconstruction Testing" Article as Contractor's responsibility.

E. Preconstruction Test Reports:

Retain "Water Analysis" Subparagraph below if chemical treatment is not specified in Section 232500 "HVAC Water Treatment."

1. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

1.5 QUALITY ASSURANCE

A. Installer Qualifications:

Retain "Installers of Pressure-Sealed Joints" Subparagraph below for pressure-sealed joints in copper or steel piping.

1. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.

Retain "Fiberglass Pipe and Fitting Installers" Subparagraph below for fiberglass pipe assembly.

2. Fiberglass Pipe and Fitting Installers: Installers of RTRF and RTRP shall be certified by manufacturer of pipes and fittings as having been trained and qualified to join fiberglass piping with manufacturer-recommended adhesive.

Retain "Steel Support Welding" and "Pipe Welding" paragraphs below for welded supports or piping. Retain "Welding certificates" Paragraph in "Informational Submittals" Article if retaining below. AWS states that welding qualifications remain in effect indefinitely unless welding personnel have not welded for more than six months or there is a specific reason to question their ability.

B. Steel Support Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

C. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

1.6 PRECONSTRUCTION TESTING

Retain this article for preconstruction testing.

A. Preconstruction Testing Service: [**Owner will engage**] [**Engage**] a qualified testing agency to perform preconstruction testing on water quality.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

Performance requirements in this article are for the piping system. Individual components may have higher pressure or temperature ratings.

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:

Pressures and temperatures below are provided for information only, and should be inserted for each Project as the working pressures and temperatures are unique.

Working pressure is equal to the relief pressure plus the static height of the system and pumping head. The only working pressure mandated by authorities having jurisdiction is for makeup water.

1. Hot-Water Heating Piping: [**100 psig**] <**Insert psig**> at [**200 deg F**] [**180 deg F**] <**Insert temperature**>.
2. Chilled-Water Piping: [**150 psig**] <**Insert psig**> at [**73 deg F**] <**Insert temperature**>.
3. Dual-Temperature Heating and Cooling Water Piping: [**100 psig**] <**Insert psig**> at [**180 deg F**] <**Insert temperature**>.
4. Condenser-Water Piping: [**150 psig**] <**Insert psig**> at [**73 deg F**] <**Insert temperature**>.
5. Glycol Cooling-Water Piping: [**150 psig**] <**Insert psig**> at [**150 deg F**] <**Insert temperature**>.
6. Makeup-Water Piping: [**80 psig**] [**150 psig**] <**Insert value**> at [**73 deg F**] [**150 deg F**] <**Insert temperature**>.
7. Condensate-Drain Piping: [**150 deg F**] [**180 deg F**] <**Insert temperature**>.
8. Blowdown-Drain Piping: [**180 deg F**] [**200 deg F**] <**Insert temperature**>.
9. Air-Vent Piping: [**180 deg F**] [**200 deg F**] <**Insert temperature**>.
10. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

First three articles below include examples of materials listed in the 2012 ASHRAE HANDBOOK - "HVAC Systems and Equipment," Ch. 46, "Pipes, Tubes, and Fittings." See "Writing Guide" Article in the Evaluations.

2.2 COPPER TUBE AND FITTINGS

Type M (Type C) in "Drawn-Temper Copper Tubing" Paragraph below is not included in Table 5, "Application of Pipe, Fittings, and Valves for Heating and Air Conditioning," in the 2012 ASHRAE HANDBOOK - "HVAC Systems and Equipment," Ch. 46, "Pipes, Tubes, and Fittings."

A. Drawn-Temper Copper Tubing: [**ASTM B 88, Type L**] [**ASTM B 88, Type M**].

Type K (Type A) in "Annealed-Temper Copper Tubing" Paragraph below is applicable for belowground installations.

B. Annealed-Temper Copper Tubing: ASTM B 88, Type K.

C. DWV Copper Tubing: ASTM B 306, Type DWV.

D. Grooved, Mechanical-Joint, Wrought-Copper Fittings: ASME B16.22.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Grooved-End Copper Fittings: ASTM B 75, copper tube or ASTM B 584, bronze casting.
3. Grooved-End-Tube Couplings: Rigid pattern unless otherwise indicated; gasketed fitting. Ductile-iron housing with keys matching pipe and fitting grooves,[**prelubricated**] EPDM gasket rated for minimum 230 deg F for use with housing, and steel bolts and nuts.

Verify that fittings in "Copper or Bronze Pressure-Seal Fittings" Paragraph below are available for pipe sizes required for Project.

E. Copper or Bronze Pressure-Seal Fittings:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Housing: Copper.
3. O-Rings and Pipe Stops: EPDM.
4. Tools: Manufacturer's special tools.
5. Minimum 200-psig working-pressure rating at 250 deg F.

Verify that fittings in "Copper, Mechanically Formed Tee Option" Paragraph below are available for pipe sizes required for Project.

F. Copper, Mechanically Formed Tee Option: For forming T-branch on copper water tube.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

G. Wrought-Copper Unions: ASME B16.22.

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" Article.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" Article.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" Article.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.

Coordinate flange class in "Cast-Iron Pipe Flanges and Flanged Fittings" Paragraph below with products in other parts of this Section and in related Sections to match face size and bolt patterns.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced as indicated in "Piping Applications" Article.

F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

G. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

H. Grooved Mechanical-Joint Fittings and Couplings:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron; ASTM A 47/A 47M, Grade 32510 malleable iron; ASTM A 53/A 53M, Type F, E, or S, Grade B fabricated steel; or ASTM A 106/A 106M, Grade B steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.
3. Couplings: Ductile- or malleable-iron housing and [**EPDM**] [**or**] [**nitrile**] gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

I. Plain-End Mechanical-Joint Couplings:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Housing: ASTM A-536 Grade 65-45-12 segmented ductile iron or type 304 stainless steel.
3. Housing coating: [**None**] <**Insert coating type**>.
4. Gasket: [**EPDM**] [**NBR**].
5. Sealing Mechanism: Double-lip sealing system or carbon steel case-hardened jaws.
6. Bolts, hex nuts, washers, or lock bars based on manufacturer's design.
7. Minimum Pressure Rating: Equal to that of the joined pipes.

J. Steel Pressure-Seal Fittings:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Housing: Steel.
3. O-Rings and Pipe Stop: EPDM.
4. Tools: Manufacturer's special tool.
5. Minimum 300-psig working-pressure rating at 230 deg F.

Non-reinforced, welded, in-branch connections weaken a main pipeline; reinforcement is necessary unless wall thickness of both mains and branches is sufficient to sustain pressure required in "Performance Requirements" Article.

K. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.4 PLASTIC PIPE AND FITTINGS

See the Evaluations for discussion of product characteristics and maximum temperatures.

A. CPVC Plastic Pipe: ASTM F 441/F 441M, with wall thickness as indicated in "Piping Applications" Article.

   1. CPVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM F 438 for Schedule 40 pipe; ASTM F 439 for Schedule 80 pipe.

B. PVC Plastic Pipe: ASTM D 1785, with wall thickness as indicated in "Piping Applications" Article.

   1. PVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM D 2466 for Schedule 40 pipe; ASTM D 2467 for Schedule 80 pipe.

"Fiberglass Pipe and Fittings" is not listed in Ch. 46, "Pipes, Tubes, and Fittings" of the 2012 ASHRAE HANDBOOK.

2.5 FIBERGLASS PIPE AND FITTINGS

Piping is available with ends for other types of joints. See the Evaluations for discussion of product characteristics and maximum temperatures and pressures.

A. RTRP: ASTM D 2996, filament-wound pipe with tapered bell and spigot ends for adhesive joints.

B. RTRF: Compression or spray-up/contact molded of same material, pressure class, and joining method as pipe.

C. Flanges: ASTM D 4024. Full-face gaskets suitable for the service, minimum 1/8-inch thick, 60-70 durometer. ASTM A 307, Grade B, hex head bolts with washers.

2.6 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

   1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated.

      a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.

b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer unless otherwise indicated.

See the Evaluations for discussions of solder and brazing materials described in "Solder Filler Metals" and "Brazing Filler Metals" paragraphs below.

D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

E. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

F. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

G. Solvent Cements for CPVC Piping: ASTM F 493.

1. <Double click to insert sustainable design text for solvent cement.>
2. <Double click to insert sustainable design text for low emitting adhesives.>

H. Solvent Cements for PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.

1. <Double click to insert sustainable design text for solvent cement.>
2. <Double click to insert sustainable design text for adhesive primer.>
3. <Double click to insert sustainable design text for low emitting adhesives.>
4. <Double click to insert sustainable design text for adhesive primer.>

I. Fiberglass Pipe Adhesive: As furnished or recommended by pipe manufacturer.

1. <Double click to insert sustainable design text for fiberglass pipe adhesive.>
2. <Double click to insert sustainable design text for low emitting adhesives.>

2.7 TRANSITION FITTINGS

A. Plastic-to-Metal Transition Fittings:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. One-piece fitting with one threaded brass or copper insert and one solvent-cement-joint end of material and wall thickness to match plastic pipe material.

B. Plastic-to-Metal Transition Unions:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Brass or copper end, solvent-cement-joint end of material and wall thickness to match plastic pipe material, rubber gasket, and threaded union.

2.8 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

Fittings in "Dielectric Unions" Paragraph below are available in NPS 1/2 to NPS 2 (DN 15 to DN 50).

B. Dielectric Unions:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description:

a. Standard: ASSE 1079.

Revise pressure rating in "Pressure Rating" Subparagraph below to suit Project, or insert other options for specific applications.

b. Pressure Rating: [**125 psig minimum at 180 deg F**] [**150 psig**] [**250 psig**] <**Insert value**>.
c. End Connections: Solder-joint copper alloy and threaded ferrous.

Fittings in "Dielectric Flanges" Paragraph below are available in NPS 1-1/2 to NPS 4 (DN 40 to DN 100).

C. Dielectric Flanges:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description:

a. Standard: ASSE 1079.
b. Factory-fabricated, bolted, companion-flange assembly.

Revise pressure rating in "Pressure Rating" Subparagraph below to suit Project, or insert other options for specific applications.

c. Pressure Rating: [**125 psig minimum at 180 deg F**] [**150 psig**] [**175 psig**] [**300 psig**] <**Insert value**>.
d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

Flanges in "Dielectric-Flange Insulating Kits" Paragraph below are available in NPS 1/2 to NPS 48 (DN 15 to DN 1200).

D. Dielectric-Flange Insulating Kits:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description:

a. Nonconducting materials for field assembly of companion flanges.

Revise pressure rating in "Pressure Rating" Subparagraph below to suit Project, or insert other options for specific applications.

b. Pressure Rating: [**150 psig**] <**Insert value**>.
c. Gasket: Neoprene or phenolic.
d. Bolt Sleeves: Phenolic or polyethylene.

e. Washers: Phenolic with steel backing washers.

Nipples in "Dielectric Nipples" Paragraph below are available in NPS 1/2 to NPS 4 (DN 15 to DN 100).

E. Dielectric Nipples:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description:

a. Standard: IAPMO PS 66.
b. Electroplated steel nipple, complying with ASTM F 1545.

Revise pressure rating and temperature in "Pressure Rating" Subparagraph below to suit Project, or insert other options for specific applications.

c. Pressure Rating: [**300 psig at 225 deg F**] <**Insert value and temperature**>.
d. End Connections: Male threaded or grooved.
e. Lining: Inert and noncorrosive, propylene.

2.9 BYPASS CHEMICAL FEEDER

Retain this article if chemical-treatment systems are not specified in Section 232500 "HVAC Water Treatment."

A. Description: Welded steel construction; 125-psig working pressure; 5-gal. capacity; with fill funnel and inlet, outlet, and drain valves.

1. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

Retain at least one pipe material in paragraphs below for each service required for Project. Services are specified separately to allow different pipe materials and joining methods for each. If materials and methods are the same for multiple services, combine the requirements by revising paragraph titles. To allow Contractor to choose among various pipe materials, retain multiple materials for each required service and pipe size. Pipe materials and joining methods in this article, in general, are as listed in the 2012 ASHRAE HANDBOOK - "HVAC Systems and Equipment," Ch. 46, "Pipes, Tubes, and Fittings." The change point for pipe materials and joining methods is specified, in this master, where the pipe size changes from NPS 2 to NPS 2-1/2 (DN 50 to DN 65). Revise this change point to suit office policy. See "Writing Guide" Article in the Evaluations.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

A. Hot-water heating piping, aboveground, [**NPS 2 and smaller**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of four subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] [**pressure-seal**] joints.
2. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**], Grade B steel pipe; [**Class 125, cast-iron**] [**Class 150, malleable-iron**] [**Class 250, cast-iron**] [**Class 300, malleable-iron**] fittings; cast-iron flanges and flange fittings; and threaded joints.
3. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.

CPVC pipe in subparagraph below has temperature and pressure limitations. See the Evaluations.

4. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

B. Hot-water heating piping, aboveground, [**NPS 2-1/2 and larger**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of five subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints.
2. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
3. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
4. [**Schedule 40**] <**Insert schedule number**> steel pipe, plain-end mechanical-coupled joints.

CPVC and RTRP in two subparagraphs below have temperature and pressure limitations. See the Evaluations.

5. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.
6. RTRP and RTRF with adhesive or flanged joints.

Retain " either of" option in first paragraph below to allow Contractor to select piping materials from those retained.

C. Hot-water heating piping installed belowground and within slabs shall be[**either of**] the following:

Retain one or both subparagraphs below. If retaining both and it is not the intent to give Contractor the choice to select materials, delete "either of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. Type K, annealed-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints. Use the fewest possible joints.

RTRP in subparagraph below has temperature and pressure limitations. See the Evaluations.

2. RTRP and RTRF with adhesive or flanged joints.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

D. Chilled-water piping, aboveground, [**NPS 2 and smaller**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of four subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] [**pressure-seal**] joints.
2. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; [**Class 125, cast-iron**] [**Class 150, malleable-iron**] [**Class 250, cast-iron**] [**Class 300, malleable-iron**] fittings; cast-iron flanges and flange fittings; and threaded joints.
3. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.

CPVC pipe in subparagraph below has temperature and pressure limitations. See the Evaluations.

4. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.

Retain "any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

E. Chilled-water piping, aboveground, [**NPS 2-1/2 and larger**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of five subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints.
2. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
3. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
4. [**Schedule 40**] <**Insert schedule number**> steel pipe, plain-end mechanical-coupled joints.

CPVC and RTRP in two subparagraphs below have temperature and pressure limitations. See the Evaluations.

5. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.
6. RTRP and RTRF with adhesive or flanged joints.

Retain " either of" option in first paragraph below to allow Contractor to select piping materials from those retained.

F. Chilled-water piping installed belowground and within slabs shall be[**either of**] the following:

Retain one or both subparagraphs below. If retaining both and it is not the intent to give Contractor the choice to select materials, delete "either of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. Type K, annealed-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints. Use the fewest possible joints.

RTRP in subparagraph below has temperature and pressure limitations. See the Evaluations.

2. RTRP and RTRF with adhesive or flanged joints.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

G. Dual-temperature heating and cooling water piping, aboveground, [**NPS 2 and smaller**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of four subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] [**pressure-seal**] joints.
2. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; [**Class 125, cast-iron**] [**Class 150, malleable-iron**] [**Class 250, cast-iron**] [**Class 300, malleable-iron**] fittings; cast-iron flanges and flange fittings; and threaded joints.
3. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.

CPVC pipe in subparagraph below has temperature and pressure limitations. See the Evaluations.

4. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

H. Dual-temperature heating and cooling water piping, aboveground, [**NPS 2-1/2 and larger**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of five subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints.
2. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

3. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
4. [**Schedule 40**] <**Insert schedule number**> steel pipe, plain-end mechanical-coupled joints.

CPVC and RTRP in two subparagraphs below have temperature and pressure limitations. See the Evaluations.

5. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.
6. RTRP and RTRF with adhesive or flanged joints.

Retain " either of" option in first paragraph below to allow Contractor to select piping materials from those retained.

I. Dual-temperature heating and cooling water piping installed belowground and within slabs shall be[**either of**] the following:

Retain one or both subparagraphs below. If retaining both and it is not the intent to give Contractor the choice to select materials, delete "either of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. Type K, annealed-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints. Use the fewest possible joints.

RTRP in subparagraph below has temperature and pressure limitations. See the Evaluations.

2. RTRP and RTRF with adhesive or flanged joints.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

J. Condenser-water piping, aboveground, [**NPS 2 and smaller**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of four subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] [**pressure-seal**] joints.
2. [**Schedule 80**] [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; [**Class 125, cast-iron**] [**Class 150, malleable-iron**] [**Class 250, cast-iron**] [**Class 300, malleable-iron**] fittings; cast-iron flanges and flange fittings; and threaded joints.
3. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.

CPVC pipe in subparagraph below has temperature and pressure limitations. See the Evaluations.

4. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

K. Condenser-water piping, aboveground, [**NPS 2-1/2 and larger**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of five subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints.
2. [**Schedule 80**] [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
3. [**Schedule 80**] [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
4. [**Schedule 40**] <**Insert schedule number**> steel pipe, plain-end mechanical-coupled joints.

CPVC and RTRP in two subparagraphs below have temperature and pressure limitations. See the Evaluations.

5. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.
6. RTRP and RTRF with adhesive or flanged joints.

Retain " either of" option in first paragraph below to allow Contractor to select piping materials from those retained.

L. Condenser-water piping installed belowground and within slabs shall be[**either of**] the following:

Retain one or both subparagraphs below. If retaining both and it is not the intent to give Contractor the choice to select materials, delete "either of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. Type K, annealed-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints. Use the fewest possible joints.

RTRP in subparagraph below has temperature and pressure limitations. See the Evaluations.

2. RTRP and RTRF with adhesive or flanged joints.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

M. Glycol cooling-water piping, aboveground, [**NPS 2 and smaller**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of four subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] [**pressure-seal**] joints.
2. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; [**Class 125, cast-iron**] [**Class 150, malleable-iron**] [**Class 250, cast-iron**] [**Class 300, malleable-iron**] fittings; cast-iron flanges and flange fittings; and threaded joints.
3. Schedule 5 steel pipe; steel, pressure-seal couplings and fittings; and pressure-seal joints.

CPVC pipe in subparagraph below has temperature and pressure limitations. See the Evaluations.

4. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.

Retain " any of" option in first paragraph below to allow Contractor to select piping materials from those retained.

N. Glycol cooling-water piping, aboveground, [**NPS 2-1/2 and larger**] <**Insert pipe size range**>, shall be[**any of**] the following:

Retain one or more of five subparagraphs below. If more than one type of material and joining method is retained and it is not the intent to give Contractor the choice to select materials, delete "any of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints.
2. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
3. [**Schedule 40**] [**Schedule 30**] [**Schedule 20**] steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
4. [**Schedule 40**] <**Insert schedule number**> steel pipe, plain-end mechanical-coupled joints.

CPVC and RTRP in two subparagraphs below have temperature and pressure limitations. See the Evaluations.

5. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings and solvent-welded joints.
6. RTRP and RTRF with adhesive or flanged joints.

Retain " either of" option in first paragraph below to allow Contractor to select piping materials from those retained.

O. Glycol cooling-water piping installed belowground and within slabs shall be[**either of**] the following:

Retain one or both subparagraphs below. If retaining both and it is not the intent to give Contractor the choice to select materials, delete "either of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. Type K, annealed-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints. Use the fewest possible joints.

RTRP in subparagraph below has temperature and pressure limitations. See the Evaluations.

2. RTRP and RTRF with adhesive or flanged joints.

Retain " either of" option in first paragraph below to allow Contractor to select piping materials from those retained.

P. Makeup-water piping installed aboveground shall be[**either of**] the following:

Retain one or both subparagraphs below. If retaining both and it is not the intent to give Contractor the choice to select materials, delete "either of" option in last paragraph above and identify each material on Drawings. Show points of transition from one material to another.

1. [**Type L**] [**Type M**], drawn-temper copper tubing, wrought-copper fittings, and [**soldered**] [**brazed**] joints.
2. [**Schedule 40**] [**Schedule 80**] CPVC plastic pipe and fittings, and solvent-welded joints.

Q. Makeup-Water Piping Installed Belowground and within Slabs: Type K, annealed-temper copper tubing, wrought-copper fittings, and soldered joints. Use the fewest possible joints.

Retain one of two "Condensate-Drain Piping" paragraphs below.

R. Condensate-Drain Piping: [**Type M**] [**Type DWV**], drawn-temper copper tubing, wrought-copper fittings, and soldered joints[**or Schedule 40 PVC plastic pipe and fittings and solvent-welded joints**].

S. Condensate-Drain Piping: Schedule 40 PVC plastic pipe and fittings and solvent-welded joints.

T. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

U. Air-Vent Piping:

1. Inlet: Same as service where installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.
2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

V. Safety-Valve-Inlet and -Outlet Piping for Hot-Water Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.

3.2 PIPING INSTALLATION

Indicate piping locations and arrangements on Drawings if such were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations.

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

H. Install fittings for changes in direction and branch connections.

I. Install piping to allow application of insulation.

J. Select system components with pressure rating equal to or greater than system operating pressure.

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using [**mechanically formed**]tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

P. Install valves according to the following:

1. Section 230523.11 "Globe Valves for HVAC Piping."
2. Section 230523.12 "Ball Valves for HVAC Piping."
3. Section 230523.13 "Butterfly Valves for HVAC Piping."
4. Section 230523.14 "Check Valves for HVAC Piping."
5. Section 230523.15 "Gate Valves for HVAC Piping."

Q. Install unions in piping, [**NPS 2**] <**Insert pipe size**> and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, [**NPS 2-1/2**] <**Insert pipe size**> and larger, at final connections of equipment and elsewhere as indicated.

S. Install shutoff valve immediately upstream of each dielectric fitting.

T. Comply with requirements in Section 230516 "Expansion Fittings and Loops for HVAC Piping" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.

U. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for identifying piping.

V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

Retain first paragraph below for piping that penetrates an exterior concrete wall or concrete slab.

W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

X. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.3 DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

B. Dielectric Fittings for [**NPS 2**] <**Insert pipe size**> and Smaller: Use dielectric [**nipples**] [**unions**].

C. Dielectric Fittings for [**NPS 2-1/2 to NPS 4**] <**Insert pipe size range**>: Use dielectric [**flanges**] [**flange kits**] [**nipples**].

D. Dielectric Fittings for [**NPS 5**] <**Insert pipe size**> and Larger: Use dielectric flange kits.

3.4 INSTALLATION OF HANGERS AND SUPPORTS

Retain first paragraph below for projects in areas that require seismic restraints.

A. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

B. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hangers, supports, and anchor devices.

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.
2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
4. Spring hangers to support vertical runs.
5. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
6. On plastic pipe, install pads or cushions on bearing surfaces to prevent hanger from scratching pipe.

D. Install hangers for [**copper tubing**] [**and**] [**steel piping**], with maximum horizontal spacing and minimum rod diameters, to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

E. Install hangers for plastic piping, with maximum horizontal spacing and minimum rod diameters, to comply with manufacturer's written instructions, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

F. Install hangers for fiberglass piping, with maximum horizontal spacing and minimum rod diameters, to comply with manufacturer's written instructions, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

G. Support horizontal piping within [**12 inches**] <**Insert dimension**> of each fitting and coupling.

H. Support vertical runs of [**copper tubing**] [**and**] [**steel piping**] to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

I. Support vertical runs of fiberglass piping to comply with manufacturer's written instructions, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

3.5 PIPE JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

H. Plastic Piping Solvent-Cemented Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:

1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
3. PVC Pressure Piping: Join ASTM D 1785 schedule number, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule number PVC pipe and socket fittings according to ASTM D 2855.
4. PVC Nonpressure Piping: Join according to ASTM D 2855.

I. Fiberglass Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer's written instructions.

Retain "Grooved Joints" Paragraph below for grooved-end pipe couplings for copper or steel pipe.

J. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid, grooved-end-pipe couplings.

Retain "Plain-End Mechanical-Coupled Joints" Paragraph below for plain-end mechanical-coupled steel pipes.

K. Plain-End Mechanical-Coupled Joints: Prepare, assemble, and test joints in accordance with manufacturer's written installation instructions.

Retain "Mechanically Formed, Copper-Tube-Outlet Joints" Paragraph below for mechanically formed outlets in place of tee fittings in copper pipe.

L. Mechanically Formed, Copper-Tube-Outlet Joints: Use manufacturer-recommended tool and procedure, and brazed joints.

Retain "Pressure-Sealed Joints" Paragraph below for pressure-sealed joints in copper or steel piping.

M. Pressure-Sealed Joints: Use manufacturer-recommended tool and procedure. Leave insertion marks on pipe after assembly.

3.6 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 230519 "Meters and Gages for HVAC Piping."

3.7 CHEMICAL TREATMENT

Delete this article if using Section 232500 "HVAC Water Treatment."

Delete first paragraph below if water analysis has been or will be conducted by Owner.

A. Perform an analysis of makeup water to determine type and quantities of chemical treatment needed to keep system free of scale, corrosion, and fouling, and to sustain the following water characteristics:

Consult water-treatment specialist and insert, in subparagraphs below, specific values required for Project.

1. pH: [**9.0 to 10.5**] <**Insert values**>.
2. "P" Alkalinity: [**100 to 500**] <**Insert values**> ppm.
3. Boron: [**100 to 200**] <**Insert values**> ppm.
4. Chemical Oxygen Demand: Maximum of [**100**] <**Insert value**> ppm. Revise this value if closed system contains glycol.
5. Corrosion Inhibitor:

Retain one of first five subparagraphs below.

   a. Sodium Nitrate: [**1000 to 1500**] <**Insert values**> ppm.
   b. Molybdate: [**200 to 300**] <**Insert values**> ppm.
   c. Chromate: [**200 to 300**] <**Insert values**> ppm.
   d. Sodium Nitrate Plus Molybdate: [**100 to 200**] <**Insert values**> ppm each.
   e. Chromate Plus Molybdate: [**50 to 100**] <**Insert values**> ppm each.

6. Soluble Copper: Maximum of [**0.20**] <**Insert value**> ppm.
7. Tolyiriazole Copper and Yellow Metal Corrosion Inhibitor: Minimum of [**10**] <**Insert value**> ppm.
8. Total Suspended Solids: Maximum of [**10**] <**Insert value**> ppm.
9. Ammonia: Maximum of [**20**] <**Insert value**> ppm.
10. Free Caustic Alkalinity: Maximum of [**20**] <**Insert value**> ppm.
11. Microbiological Limits:

   a. Total Aerobic Plate Count: Maximum of [**1000**] <**Insert number**> organisms/mL.
   b. Total Anaerobic Plate Count: Maximum of [**100**] <**Insert number**> organisms/mL.
   c. Nitrate Reducers: [**100**] <**Insert number**> organisms/mL.
   d. Sulfate Reducers: Maximum of [**zero**] <**Insert number**> organisms/mL.
   e. Iron Bacteria: Maximum of [**zero**] <**Insert number**> organisms/mL.

12. <**Insert other requirements if necessary**>.

Retain first paragraph below if chemical water treatment is not specified in Section 232500 "HVAC Water Treatment." Coordinate floor drain location for equipment drain near feeder.

B. Install bypass chemical feeders in each hydronic system where indicated.

1. Install in upright position with top of funnel not more than 48 inches above the floor.

2. Install feeder in minimum NPS 3/4 bypass line, from main with full-size, full-port, ball valve in the main between bypass connections.
3. Install NPS 3/4 pipe from chemical feeder drain to nearest equipment drain and include a full-size, full-port, ball valve.

C. Fill system with fresh water and add liquid alkaline compound with emulsifying agents and detergents to remove grease and petroleum products from piping. Circulate solution for a minimum of 24 hours, drain, clean strainer screens, and refill with fresh water.

D. Add initial chemical treatment and maintain water quality in ranges noted above for the first year of operation.

E. Fill systems that have antifreeze or glycol solutions with the following concentrations:

1. Hot-Water Heating Piping: Minimum of <**Insert number**> percent [**ethylene**] [**propylene**] glycol.
2. Chilled-Water Piping: Minimum of <**Insert number**> percent [**ethylene**] [**propylene**] glycol.
3. Dual-Temperature Heating and Cooling Water Piping: Minimum of <**Insert number**> percent [**ethylene**] [**propylene**] glycol.
4. Glycol Cooling-Water Piping: Minimum of <**Insert number**> percent [**ethylene**] [**propylene**] glycol.

3.8 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:

Procedures in subparagraphs below are paraphrased from ASME B31.9.

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to

pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."

5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

C. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
7. Verify lubrication of motors and bearings.

END OF SECTION 232113

SECTION 232116 - HYDRONIC PIPING SPECIALTIES

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Hydronic specialty valves.
2. Air-control devices.
3. Strainers.
4. Connectors.

B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 230516 "Expansion Fittings and Loops for HVAC Piping" for expansion fittings and loops.
2. Section 230523.11 "Globe Valves for HVAC Piping" for specification and installation requirements for globe valves common to most piping systems.
3. Section 230523.12 "Ball Valves for HVAC Piping" for specification and installation requirements for ball valves common to most piping systems.
4. Section 230523.13 "Butterfly Valves for HVAC Piping" for specification and installation requirements for butterfly valves common to most piping systems.
5. Section 230523.14 "Check Valves for HVAC Piping" for specification and installation requirements for check valves common to most piping systems.
6. Section 230523.15 "Gate Valves for HVAC Piping" for specification and installation requirements for gate valves common to most piping systems.
7. Section 230923.11 "Control Valves" for automatic control valve and sensor specifications, installation requirements, and locations.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product:

1. Include construction details and material descriptions for hydronic piping specialties.
2. Include rated capacities, operating characteristics, and furnished specialties and accessories.
3. Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For hydronic piping specialties to include in emergency, operation, and maintenance manuals.

1.5 MAINTENANCE MATERIAL SUBMITTALS

Retain "Differential Pressure Meter" Paragraph below if retaining calibrated-orifice, balancing valves in Part 2.

A. Differential Pressure Meter: For each type of balancing valve and automatic flow control valve, include flowmeter, probes, hoses, flow charts, and carrying case.

1.6 QUALITY ASSURANCE

A. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

B. Safety Valves and Pressure Vessels: Shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 HYDRONIC SPECIALTY VALVES

MSS SP-122, "Plastic Industrial Ball Valves," is a standard for plastic ball valves. It is not comprehensive and additional data may be required for certain applications. In general, end types and pressure and temperature ratings are required. No applicable standards are available for plastic butterfly or check valves. CPVC piping in this Section is rated for up to 180 deg F (82 deg C). Verify that plastic valves are adequate for operating temperature of piping systems.

A. Plastic Ball Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: One-, two-, or three-piece CPVC or PVC to match piping.
3. Ball: Full-port CPVC or PVC to match piping.
4. Seats: PTFE.
5. Seals: EPDM.
6. End Connections: Socket, union, or flanged.
7. Handle Style: Tee shape.
8. CWP Rating: Equal to piping service.
9. Maximum Operating Temperature: Equal to piping service.

Not all manufacturers comply with the standard in subparagraph below.

10. Comply with MSS SP-122.

Large plastic butterfly valves may have reduced pressure ratings.

B. Plastic Butterfly Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: PVC or CPVC to match piping wafer type for installation between flanges.
3. Disc: EPDM-coated steel.
4. Seats: PTFE.
5. Handle Style: Locking lever.
6. CWP Rating: Equal to piping service.
7. Maximum Operating Temperature: Equal to piping service.

C. Plastic Check Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Bronze, ball or plug type with calibrated orifice or venturi.
3. Ball: Brass or stainless steel.
4. Plug: Resin.
5. Seat: PTFE.
6. End Connections: Threaded or socket.
7. Pressure Gage Connections: Integral seals for portable differential pressure meter.
8. Handle Style: Lever, with memory stop to retain set position.
9. CWP Rating: Minimum 125 psig.
10. Maximum Operating Temperature: 250 deg F.

D. Bronze, Calibrated-Orifice, Balancing Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Bronze, ball or plug type with calibrated orifice or venturi.
3. Ball: Brass or stainless steel.
4. Plug: Resin.
5. Seat: PTFE.
6. End Connections: Threaded or socket.
7. Pressure Gage Connections: Integral seals for portable differential pressure meter.
8. Handle Style: Lever, with memory stop to retain set position.
9. CWP Rating: Minimum 125 psig.
10. Maximum Operating Temperature: 250 deg F.

E. Cast-Iron or Steel, Calibrated-Orifice, Balancing Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
3. Ball: Brass or stainless steel.
4. Stem Seals: EPDM O-rings.
5. Disc: Glass and carbon-filled PTFE.
6. Seat: PTFE.
7. End Connections: Flanged or grooved.
8. Pressure Gage Connections: Integral seals for portable differential pressure meter.
9. Handle Style: Lever, with memory stop to retain set position.
10. CWP Rating: Minimum 125 psig.
11. Maximum Operating Temperature: 250 deg F.

F. Diaphragm-Operated, Pressure-Reducing Valves: ASME labeled.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Low inlet-pressure check valve.
8. Inlet Strainer: <**Insert materials**>, removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.

10. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

G. Diaphragm-Operated Safety Valves: ASME labeled.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Wetted, Internal Work Parts: Brass and rubber.
8. Inlet Strainer: <**Insert materials**>, removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.
10. Valve Size, Capacity, and Operating Pressure: Comply with ASME Boiler and Pressure Vessel Code: Section IV, and selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

H. Automatic Flow-Control Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Brass or ferrous metal.
3. Flow Control Assembly, provide either of the following:

    a. Piston and Spring Assembly: [**Stainless steel**] [**Corrosion resistant**], tamper proof, self-cleaning, and removable.
    b. Elastomeric Diaphragm and Polyphenylsulfone Orifice Plate: Operating ranges within 2- to 80-psig differential pressure.

4. Combination Assemblies: Include bronze or brass-alloy ball valve.
5. Identification Tag: Marked with zone identification, valve number, and flow rate.
6. Size: Same as pipe in which installed.
7. Performance: Maintain constant flow within plus or minus 10 percent, regardless of system pressure fluctuations.
8. Minimum CWP Rating: [**175 psig**] [**300 psig**].
9. Maximum Operating Temperature: [**200 deg F**] [**250 deg F**].

2.2 AIR-CONTROL DEVICES

Air vents aid in system filling. Air removal after initial startup is accomplished by air separator or boiler dip-tube.

Leakage from automatic air vents may cause damage to ceilings and other finished surfaces. Manual air vents may be preferred over automatic air vents in finished spaces.

A. Manual Air Vents:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Bronze.
3. Internal Parts: Nonferrous.

4. Operator: Screwdriver or thumbscrew.
5. Inlet Connection: NPS 1/2.
6. Discharge Connection: NPS 1/8.
7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 225 deg F.

B. Automatic Air Vents:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Bronze or cast iron.
3. Internal Parts: Nonferrous.
4. Operator: Noncorrosive metal float.
5. Inlet Connection: NPS 1/2.
6. Discharge Connection: NPS 1/4.
7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 240 deg F.

C. Expansion Tanks:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Tank: Welded steel, rated for 125-psig working pressure and 375 deg F maximum operating temperature, with taps in bottom of tank for tank fitting and taps in end of tank for gage glass. Tanks shall be factory tested after taps are fabricated and shall be labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. Air-Control Tank Fitting: Cast-iron body, copper-plated tube, brass vent tube plug, and stainless-steel ball check, 100-gal. unit only; sized for compression-tank diameter. Provide tank fittings for 125-psig working pressure and 250 deg F maximum operating temperature.
4. Tank Drain Fitting: Brass body, nonferrous internal parts; 125-psig working pressure and 240 deg F maximum operating temperature; constructed to admit air to compression tank, drain water, and close off system.
5. Gage Glass: Full height with dual manual shutoff valves, [**3/4-inch-**] <**Insert dimension**> diameter gage glass, and slotted-metal glass guard.

D. [**Diaphragm**] [**Bladder**]-Type ASME Expansion Tanks:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Tank: Welded steel, rated for 125-psig working pressure and 375 deg F maximum operating temperature. Factory test after taps are fabricated and supports installed and are labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. [**Diaphragm**] [**Bladder**]: Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.
4. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

E. Diaphragm-Type Non-ASME Expansion Tanks:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Tank: Carbon steel, rated for minimum 100-psig working pressure at minimum 200 deg F maximum operating temperature. Non-ASME construction.
3. Diaphragm: Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.

F. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

G. Coalescing-Type Air and Dirt Separators:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Tank: Fabricated steel tank; ASME constructed and stamped for 125-psig (862-kPa) working pressure and 270 deg F (130 deg C) maximum operating temperature.

Not all manufacturers offer the coalescing mediums listed below. Coordinate with retained manufacturers.

3. Coalescing Medium: [**Copper**] [**Stainless steel**] <**Insert material**>.
4. Air Vent: Threaded to the top of the separator.
5. Inline Inlet and Outlet Connections: Threaded for NPS 2 (DN 50) and smaller; Class 150 flanged connections for NPS 2-1/2 (DN 65) and larger.
6. Blowdown Connection: Threaded to the bottom of the separator.
7. Size: Match system flow capacity.

H. Tangential-Type Air Separators:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Tank: Welded steel; ASME constructed and labeled for 125-psig minimum working pressure and 375 deg F maximum operating temperature.
3. Air Collector Tube: Perforated stainless steel, constructed to direct released air into expansion tank.
4. Tangential Inlet and Outlet Connections: Threaded for NPS 2 and smaller; flanged connections for NPS 2-1/2 and larger.
5. Blowdown Connection: Threaded.
6. Size: Match system flow capacity.

I. In-Line Air Separators:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Tank: One-piece cast iron with an integral weir constructed to decelerate system flow to maximize air separation.
3. Maximum Working Pressure: Up to 175 psig.
4. Maximum Operating Temperature: Up to 300 deg F.

J. Air Purgers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Cast iron with internal baffles that slow the water velocity to separate the air from solution and divert it to the vent for quick removal.
3. Maximum Working Pressure: 150 psig.
4. Maximum Operating Temperature: 250 deg F.

2.3 STRAINERS

A. Y-Pattern Strainers:

1. Body: ASTM A126, Class B, cast iron with bolted cover and bottom drain connection.

2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.

In "Strainer Screen" Subparagraph below, larger mesh numbers have larger passages, thus allowing larger objects to pass.

3. Strainer Screen: Stainless-steel, [**20**] [**40**] [**60**]-mesh strainer, or perforated stainless-steel basket.
4. CWP Rating: 125 psig.

B. Basket Strainers:

1. Body: ASTM A126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
3. Strainer Screen: [**40**] [**60**]-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig.

C. T-Pattern Strainers:

1. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
2. End Connections: Grooved ends.
3. Strainer Screen: [**40**] [**60**]-mesh startup strainer, and perforated stainless-steel basket with 57 percent free area.
4. CWP Rating: 750 psig.

2.4 CONNECTORS

Retain "Stainless-Steel Bellow, Flexible Connectors" Paragraph below for small pipe sizes. Allow sufficient length for installation. Where space is limited and for larger piping applications, consider using flexible joints and spherical connectors.

A. Stainless-Steel Bellow, Flexible Connectors:

1. Body: Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
2. End Connections: Threaded or flanged to match equipment connected.
3. Performance: Capable of 3/4-inch misalignment.
4. CWP Rating: 150 psig.
5. Maximum Operating Temperature: 250 deg F.

B. Spherical, Rubber, Flexible Connectors:

1. Body: Fiber-reinforced rubber body.
2. End Connections: Steel flanges drilled to align with Classes 150 and 300 steel flanges.
3. Performance: Capable of misalignment.
4. CWP Rating: 150 psig.
5. Maximum Operating Temperature: 250 deg F.

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

A. Install shutoff-duty valves at each branch connection to supply mains and at supply connection to each piece of equipment.

B. Install [**throttling-duty**] [**calibrated-orifice, balancing**] valves at each branch connection to return main.

C. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.

D. Install check valves at each pump discharge and elsewhere as required to control flow direction.

E. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.

F. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

3.2 HYDRONIC SPECIALTIES INSTALLATION

Retain one of first two paragraphs below. Leakage from automatic air vents may cause damage to ceilings and other finished surfaces. Air vents aid in system filling. Air removal after initial startup is accomplished by air separator or boiler dip-tube. Manual air vents may be a better solution.

A. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.

B. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting.

C. Install piping from boiler air outlet, air separator, or air purger to expansion tank with a 2 percent upward slope toward tank.

Retain one of first two paragraphs below according to air separator specified in Part 2.

D. Install in-line air separators in pump suction. Install drain valve on air separators NPS 2 and larger.

E. Install tangential air separator in pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.

Retain one of two paragraphs below.

F. Install expansion tanks above the air separator. Install tank fitting in tank bottom and charge tank. Use manual vent for initial fill to establish proper water level in tank.

1. Install tank fittings that are shipped loose.

2. Support tank from floor or structure above with sufficient strength to carry weight of tank, piping connections, fittings, plus tank full of water. Do not overload building components and structural members.

G. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure that tank is properly charged with air to suit system Project requirements.

END OF SECTION 232116

SECTION 232123 - HYDRONIC PUMPS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Close-coupled, in-line centrifugal pumps.
2. Close-coupled, end-suction centrifugal pumps.
3. Separately coupled, horizontally mounted, in-line centrifugal pumps.
4. Separately coupled, vertically mounted, in-line centrifugal pumps.
5. Separately coupled, base-mounted, end-suction centrifugal pumps.
6. Separately coupled, base-mounted, double-suction centrifugal pumps.
7. Separately coupled, vertically mounted, double-suction centrifugal pumps.
8. Separately coupled, vertically mounted, turbine centrifugal pumps.
9. Wet-rotor pumps.
10. Automatic condensate pump units.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. ECM: Electronically commutated motor.

B. EPDM: Ethylene propylene diene monomer.

C. EPR: Ethylene propylene rubber.

D. FKM: Fluoroelastomer polymer.

E. HI: Hydraulic Institute.

F. NBR: Nitrile rubber or Buna-N.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of pump.

1. Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated.
2. Indicate pump's operating point on curves.

B. Shop Drawings: For each pump.

1. Show pump layout and connections.
2. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.
3. Include diagrams for power, signal, and control wiring.

C. Delegated-Design Submittal: For each pump.

Retain subparagraph below if pumps are required to withstand specific design loads and Architect either has delegated design responsibility to Contractor or wants to review structural data as another way to verify equipment's compliance with performance requirements. Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

1. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.

   a. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.
   b. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Plans, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.

Retain "Seismic Qualification Data" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

B. Seismic Qualification Data: Certificates for pumps, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

Revise "Mechanical Seals" Subparagraph below to suit Project.

1. Mechanical Seals: [**One**] <**Insert number**> mechanical seal(s) for each pump.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain "Delegated Design" Paragraph below if Contractor is required to assume responsibility for design.

B. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design vibration isolation[**and seismic restraints**].

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Data" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

C. Seismic Performance: Pumps shall withstand the effects of earthquake motions determined in accordance with [**ASCE/SEI 7**] <**Insert requirement**>.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: [**1.5**] [**1.0**].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. <**Insert requirements for Component Amplification Factor and Component Response Modification Factor**>.

2.2 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically.

D. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gauge tappings at inlet and outlet[**, replaceable bronze wear rings,**] and threaded [**companion-flange**] [**union-end**] connections.
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.

Retain "Pump Shaft Sleeve" or "Pump Stub Shaft" Subparagraph below. Some larger in-line close-coupled pumps have a stub shaft rigidly attached to the motor shaft without a bearing or flexible connector to make disassembly easier. Consult manufacturers.

3. Pump Shaft Sleeve: [**Bronze**] [**Type 304 stainless steel**].
4. Pump Stub Shaft: [**Type 304**] [**Type 316**] stainless steel.

In "Seal" Subparagraph below, verify suitable bellows and gasket materials if pumped fluids operate above 200 deg F (93 deg C) or contain glycol. If fluid pH is maintained above 9.0 or if fluid contains more than 400 ppm of dissolved solids or 20 ppm of undissolved solids, consider using silicon carbide stationary and rotating rings.

5. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**NBR**] [**EPDM**] [**FKM**] <**Insert material**> rubber bellows and gasket. Include water slinger on shaft between motor and seal.
6. Seal Flushing: Flush, cool, and lubricate pump seal by directing pump discharge water to flow over the seal.

Delete "Shaft Coupling" Subparagraph if rigid, axially-split spacer coupling is not used and impeller is mounted directly onto motor shaft.

E. Shaft Coupling: Rigid, axially-split spacer coupling to allow service of pump seal without disturbing pump or motor.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

F. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

In "Enclosure" Subparagraph below, coordinate type availability with equipment manufacturers.

1. Enclosure : [**Totally enclosed, fan cooled**] <**Insert enclosure type**>.

Retain first subparagraph below for premium efficiency.

2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Single**] [**Variable**]-speed motor.

Delete first subparagraph below if pump is single speed or if variable-frequency motor controller is to be provided under Section 262923 "Variable-Frequency Motor Controllers."

6. Provide integral pump motor variable-speed controller.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

7. <**Insert unique motor characteristics**>.

If Project has more than one type or configuration of close-coupled, in-line centrifugal pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

G. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Maximum Operating Pressure: [**175 psig**] [**250 psig**] <**Insert value**>.
4. Maximum Continuous Operating Temperature: [**225 deg F**] [**250 deg F**] <**Insert temperature**>.
5. Inlet and Outlet Size: <**Insert NPS**>.
6. Impeller Size: <**Insert inches**>.
7. Motor Speed: <**Insert rpm**>.
8. Motor Horsepower: <**Insert value**>.
9. Electrical Characteristics:

a. Volts: [**120**] [**240**] [**208**] [**460**] <**Insert value**> V.
b. Phase: [**Single**] [**Three**].
c. Hertz: 60 Hz.
d. Full-Load Amperes: <**Insert value**> A.
e. Minimum Circuit Ampacity: <**Insert value**> A.
f. Maximum Overcurrent Protection: <**Insert value**> A.

2.3 CLOSE-COUPLED, END-SUCTION CENTRIFUGAL PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally.

D. Pump Construction:

1. Casing: Radially split, cast iron, with[**replaceable bronze wear rings,**] drain plug at bottom and air vent at top of volute, threaded gauge tappings at inlet and outlet, and [**threaded companion-flange**] [**flanged**] connections.

2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.

Retain "Pump Shaft Sleeve" or "Pump Stub Shaft" Subparagraph below. Some larger in-line close-coupled pumps have a stub shaft rigidly attached to the motor shaft without a bearing or flexible connector to make disassembly easier. Consult manufacturers.

3. Pump Shaft Sleeve: [**Bronze**] [**Type 304 stainless steel**].
4. Pump Stub Shaft: [**Type 304**] [**Type 316**] stainless steel.

In "Seal" Subparagraph below, verify suitable bellows and gasket materials if pumped fluids operate above 225 deg F (107 deg C) or contain glycol.

5. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**NBR**] [**EPDM**] [**FKM**] bellows and gasket. Include water slinger on shaft between motor and seal.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

E. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

In "Enclosure" Subparagraph below, coordinate type availability with equipment manufacturers.

1. Enclosure: [**Totally enclosed, fan cooled**] <**Insert enclosure type**>.

Retain first subparagraph below for premium efficiency.

2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Single**] [**Variable**]-speed motor.

Delete first subparagraph below if pump is single speed or if variable-frequency motor controller is to be provided under Section 262923 "Variable-Frequency Motor Controllers."

6. Provide integral pump motor variable-speed controller.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

7. <**Insert unique motor characteristics**>.

If Project has more than one type or configuration of close-coupled, end-suction centrifugal pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

F. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Maximum Operating Pressure: [**175 psig**] <**Insert value**>.

4. Maximum Continuous Operating Temperature: [**225 deg F**] [**250 deg F**] <**Insert temperature**>.
5. Inlet and Outlet Size: <**Insert NPS**>.
6. Impeller Size: <**Insert inches**>.
7. Motor Speed: <**Insert rpm**>.
8. Motor Horsepower: <**Insert value**>.
9. Electrical Characteristics:

   a. Volts: [**120**] [**240**] [**208**] [**460**] <**Insert value**> V.
   b. Phase: [**Single**] [**Three**].
   c. Hertz: 60 Hz.
   d. Full-Load Amperes: <**Insert value**> A.
   e. Minimum Circuit Ampacity: <**Insert value**> A.
   f. Maximum Overcurrent Protection: <**Insert value**> A.

2.4 SEPARATELY COUPLED, HORIZONTALLY MOUNTED, IN-LINE CENTRIFUGAL PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally.

D. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gauge tappings at inlet and outlet, and threaded [**companion-flange**] [**union-end**] connections.
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, and keyed to shaft. For pumps that are not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: [**Carbon steel, with copper-alloy shaft sleeve**] [**Type 304 stainless steel**] [**Type 316 stainless steel**].

In "Seal" Subparagraph below, verify suitable bellows and gasket materials if pumped fluids operate above 225 deg F (107 deg C) or contain glycol.

4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**NBR**] [**EPDM**] [**FKM**] <**Insert material**> bellows and gasket.
5. Pump Bearings: [**Permanently lubricated ball bearings**] [**Grease lubricated ball bearings**].

E. Shaft Coupling: [**Molded-rubber insert with interlocking spider**] [**Interlocking frame with interconnecting springs**] capable of absorbing vibration.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

F. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

In "Enclosure" Subparagraph below, coordinate type availability with equipment manufacturers.

1. Enclosure Type: [**Totally enclosed, fan cooled**] <**Insert enclosure type**>.

Retain first subparagraph below for premium efficiency.

2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Single**] [**Variable**]-speed motor.

Delete first subparagraph below if pump is single speed or if variable-frequency motor controller is to be provided under Section 262923 "Variable-Frequency Motor Controllers."

6. Provide integral pump motor variable-speed controller.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

7. <**Insert unique motor characteristics**>.

If Project has more than one type or configuration of separately coupled, horizontally mounted, in-line centrifugal pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

G. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Maximum Operating Pressure: [**175 psig**] <**Insert value**>.
4. Maximum Continuous Operating Temperature: [**225 deg F**] [**250 deg F**] <**Insert temperature**>.
5. Inlet and Outlet Size: <**Insert NPS**>.
6. Impeller Size: <**Insert inches**>.
7. Motor Speed: <**Insert rpm**>.
8. Motor Horsepower: <**Insert value**>.
9. Electrical Characteristics:

   a. Volts: [**120**] [**240**] [**208**] [**460**] <**Insert value**> V.
   b. Phase: [**Single**] [**Three**].
   c. Hertz: 60 Hz.
   d. Full-Load Amperes: <**Insert value**> A.
   e. Minimum Circuit Ampacity: <**Insert value**> A.
   f. Maximum Overcurrent Protection: <**Insert value**> A.

2.5 SEPARATELY COUPLED, VERTICALLY MOUNTED, IN-LINE CENTRIFUGAL PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically.

D. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gauge tappings at inlet and outlet[**, replaceable bronze wear rings,**] and threaded [**companion-flange**] [**union-end**] connections.
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For pumps that are not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: [**Carbon steel, with copper-alloy shaft sleeve**] [**Type 304 stainless steel**] [**Type 316 stainless steel**].

In "Seal" Subparagraph below, verify suitable bellows and gasket materials if pumped fluids operate above 225 deg F (107 deg C) or contain glycol.

4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**NBR**] [**EPDM**] [**FKM**] <**Insert material**> bellows and gasket.

E. Shaft Coupling: [**Molded-rubber insert with interlocking spider**] [**Interlocking frame with interconnecting springs**] capable of absorbing vibration.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

F. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

In "Enclosure" Subparagraph below, coordinate type availability with equipment manufacturers.

1. Enclosure: [**Totally enclosed, fan cooled**] <**Insert enclosure type**>.

Retain first subparagraph below for premium efficiency.

2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Single**] [**Variable**]-speed motor.

Delete first subparagraph below if pump is single speed or if variable-frequency motor controller is to be provided under Section 262923 "Variable-Frequency Motor Controllers."

6. Provide integral pump motor variable-speed controller.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

7. <**Insert unique motor characteristics**>.

If Project has more than one type or configuration of separately coupled, vertically mounted, in-line centrifugal pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

G. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Maximum Operating Pressure: [**175 psig**] [**250 psig**] <**Insert value**>.
4. Maximum Continuous Operating Temperature: [**225 deg F**] [**250 deg F**] <**Insert temperature**>.
5. Inlet and Outlet Size: <**Insert NPS**>.
6. Impeller Size: <**Insert inches**>.
7. Motor Speed: <**Insert rpm**>.
8. Motor Horsepower: <**Insert value**>.
9. Electrical Characteristics:

a. Volts: [**120**] [**240**] [**208**] [**460**] <**Insert value**> V.
b. Phase: [**Single**] [**Three**].
c. Hertz: 60 Hz.
d. Full-Load Amperes: <**Insert value**> A.
e. Minimum Circuit Ampacity: <**Insert value**> A.
f. Maximum Overcurrent Protection: <**Insert value**> A.

2.6 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump with flexible shaft coupling as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal.

D. Pump Construction:

Not all manufacturers provide volute supports that allow removal and replacement of impeller without disconnecting piping.

1. Casing: Radially split, cast iron, with[**replaceable bronze wear rings,**] threaded gauge tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and [**threaded companion-flange**] [**flanged**] connections.[**Provide integral mount on volute to support the casing, and provide attached piping to allow removal and replacement of impeller without disconnecting piping or requiring realignment of pump and motor shaft.**]
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For pumps that are not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: [**Carbon steel, with copper-alloy shaft sleeve**] [**Type 304 stainless steel**] [**Type 316 stainless steel**].

Retain "Seal, Mechanical Type" or "Seal, Packing Type" Subparagraph below. If retaining first subparagraph, verify suitable bellows and gasket materials if pumped fluids above 225 deg F (107 deg C) or containing glycol.

4. Seal, Mechanical Type: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**NBR**] [**EPDM**] [**FKM**] <**Insert material**> bellows and gasket.
5. Seal, Packing Type: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
6. Pump Bearings: Grease-lubricated ball bearings in cast-iron housing with grease fittings.

Not all manufacturers provide drop-out coupling that allows removal and replacement of impeller without disconnecting piping. This device is required with volute support described in "Casing" Subparagraph.

E. Shaft Coupling: Molded-rubber insert and interlocking spider capable of absorbing vibration. [**Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor**] [**EPDM coupling sleeve for variable-speed applications**].

F. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

G. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A36/A36M channels and angles. Fabricate to mount pump casing, coupling guard, and motor.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

H. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

In "Enclosure" Subparagraph below, coordinate type availability with equipment manufacturers.

1. Enclosure: [**Totally enclosed, fan cooled**] <**Insert enclosure type**>.

Retain first subparagraph below for premium efficiency.

2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Single**] [**Variable**]-speed motor.

Delete first subparagraph below if pump is single speed or if variable-frequency motor controller is to be provided under Section 262923 "Variable-Frequency Motor Controllers."

6. Provide integral pump motor variable-speed controller.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

7. <**Insert unique motor characteristics**>.

If Project has more than one type or configuration of separately coupled, base-mounted, end-suction centrifugal pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

I. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Maximum Operating Pressure: [**175 psig**] [**250 psig**] <**Insert value**>.
4. Maximum Continuous Operating Temperature: [**225 deg F**] [**250 deg F**] <**Insert temperature**>.
5. Inlet and Outlet Size: <**Insert NPS**>.
6. Impeller Size: <**Insert inches**>.
7. Motor Speed: <**Insert rpm**>.
8. Motor Horsepower: <**Insert value**>.
9. Electrical Characteristics:

   a. Volts: [**120**] [**240**] [**208**] [**460**] <**Insert value**> V.
   b. Phase: [**Single**] [**Three**].
   c. Hertz: 60 Hz.
   d. Full-Load Amperes: <**Insert value**> A.
   e. Minimum Circuit Ampacity: <**Insert value**> A.
   f. Maximum Overcurrent Protection: <**Insert value**> A.

2.7 SEPARATELY COUPLED, BASE-MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, impeller-between-bearings, separately coupled, double-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal.

D. Pump Construction:

Not all manufacturers provide casing supports that allow removal and replacement of impeller without disconnecting piping. If retaining this option, also retain drop-out coupling described in "Shaft Coupling" Paragraph below.

1. Casing: [**Radially**] [**Horizontally**] split, cast iron, with[**replaceable bronze wear rings,**] threaded gauge tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and ASME B16.1, [**Class 125**] [**Class 250**] flanges.[**Casing supports shall allow removal and replacement of impeller without disconnecting piping.**]
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, and keyed to shaft. For pumps that are not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: [**Type 304**] [**Type 316**] stainless steel.

Retain "Seal, Mechanical Type" or "Seal, Packing Type" Subparagraph below. If retaining first subparagraph, verify suitable bellows and gasket materials if pumped fluids operate above 225 deg F (107 deg C) or contain glycol.

4. Seal, Mechanical Type: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**NBR**] [**EPDM**] [**FKM**] <**Insert material**> bellows and gasket.
5. Seal, Packing Type: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
6. Pump Bearings: Grease-lubricated ball bearings in cast-iron housing with grease fittings.

Not all manufacturers provide drop-out coupling that allows removal and replacement of impeller without disconnecting piping. This device is required with casing support described in "Casing" Subparagraph.

E. Shaft Coupling: Molded-rubber insert and interlocking spider capable of absorbing vibration. [**Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor**] [**EPDM coupling sleeve for variable-speed applications**].

F. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

G. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A36/A36M channels and angles. Fabricate to mount pump casing, coupling guard, and motor.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

H. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

In "Enclosure" Subparagraph below, coordinate type availability with equipment manufacturers.

1. Enclosure: [**Totally enclosed, fan cooled**] <**Insert enclosure type**>.

Retain first subparagraph below for premium efficiency.

2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Single**] [**Variable**]-speed motor.

Delete first subparagraph below if pump is single speed or if variable-frequency motor controller is to be provided under Section 262923 "Variable-Frequency Motor Controllers."

6. Provide integral pump motor variable-speed controller.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

7. <**Insert unique motor characteristics**>.

If Project has more than one type or configuration of separately coupled, base-mounted, double-suction centrifugal pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

I. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Maximum Operating Pressure: [**175 psig**] [**250 psig**] <**Insert value**>.
4. Maximum Continuous Operating Temperature: [**225 deg F**] [**250 deg F**] <**Insert temperature**>.
5. Inlet and Outlet Size: <**Insert NPS**>.
6. Impeller Size: <**Insert inches**>.
7. Motor Speed: <**Insert rpm**>.
8. Motor Horsepower: <**Insert value**>.
9. Electrical Characteristics:

a. Volts: [**120**] [**240**] [**208**] [**460**] <**Insert value**> V.
b. Phase: [**Single**] [**Three**].
c. Hertz: 60 Hz.
d. Full-Load Amperes: <**Insert value**> A.
e. Minimum Circuit Ampacity: <**Insert value**> A.
f. Maximum Overcurrent Protection: <**Insert value**> A.

2.8 SEPARATELY COUPLED, VERTICALLY MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, impeller-between-bearings, separately coupled, double-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically.

D. Pump Construction:

1. Casing: Radially split, cast iron, with[**replaceable bronze wear rings,**] threaded gauge tappings at inlet and outlet, drain plug at bottom of volute, mounting support, and ASME B16.1, [**Class 125**] [**Class 250**] flanges.
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, and keyed to shaft. For pumps that are not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: [**Type 304 stainless steel**] [**Type 316 stainless steel**] <**Insert material**>.

Retain "Seal, Mechanical Type" or "Seal, Packing Type" Subparagraph below. If retaining first subparagraph, verify suitable bellows and gasket materials if pumped fluids operate above 225 deg F (107 deg C) or contain glycol.

4. Seal, Mechanical Type: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**NBR**] [**EPDM**] [**FKM**] <**Insert material**> bellows and gasket.
5. Seal, Packing Type: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
6. Pump Bearings: Grease-lubricated ball bearings in cast-iron housing with grease fittings.

E. Shaft Coupling: Molded-rubber insert and interlocking spider capable of absorbing vibration.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

F. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

In "Enclosure" Subparagraph below, coordinate type availability with equipment manufacturers.

1. Enclosure: [**Totally enclosed, fan cooled**] <**Insert enclosure type**>.

Retain first subparagraph below for premium efficiency.

2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Single**] [**Variable**]-speed motor.

Delete first subparagraph below if pump is single speed or if variable-frequency motor controller is to be provided under Section 262923 "Variable-Frequency Motor Controllers."

6. Provide integral pump motor variable-speed controller.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

7. <**Insert unique motor characteristics**>.

If Project has more than one type or configuration of separately coupled, vertically mounted, double-suction centrifugal pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

G. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Maximum Operating Pressure: [**175 psig**] [**250 psig**] <**Insert value**>.
4. Maximum Continuous Operating Temperature: [**225 deg F**] [**250 deg F**] <**Insert temperature**>.
5. Inlet and Outlet Size: <**Insert NPS**>.
6. Impeller Size: <**Insert inches**>.
7. Motor Speed: <**Insert rpm**>.
8. Motor Horsepower: <**Insert value**>.

9. Electrical Characteristics:

   a. Volts: [**120**] [**240**] [**208**] [**460**] <**Insert value**> V.
   b. Phase: [**Single**] [**Three**].
   c. Hertz: 60 Hz.
   d. Full-Load Amperes: <**Insert value**> A.
   e. Minimum Circuit Ampacity: <**Insert value**> A.
   f. Maximum Overcurrent Protection: <**Insert value**> A.

2.9 SEPARATELY COUPLED, VERTICALLY MOUNTED, TURBINE CENTRIFUGAL PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, [**single-stage**] [**multistage**], centrifugal, impeller-between-bearings, end-suction pump as defined in HI 2.1-2.2 and HI 2.3; designed for installation with pump and motor shafts mounted vertically and projecting into a sump.

D. Pump Construction:

1. Pump Bowl: Cast iron, with [**cone**] [**basket**] strainer[**, replaceable bronze wear ring,**] and suction bell.[**Water passages of intermediate bowls shall be coated with porcelain enamel.**]
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced and keyed to shaft. For pumps that are not frequency-drive controlled, trim impeller to match specified performance.
3. Pump Shaft: [**Carbon**] [**Type 304 stainless**] [**Type 316 stainless**] steel sized in accordance with manufacturer's written instructions.
4. Pump Bearings: Water-lubricated bronze and rubber sleeve bearings in cast-iron housing.
5. Pump Column: ASTM A53/A53M, Grade B steel pipe.

Retain "Seal, Mechanical Type" or "Seal, Packing Type" Subparagraph below. If retaining first subparagraph, verify suitable bellows and gasket materials if pumped fluids operate above 225 deg F (107 deg C) or contain glycol.

6. Seal, Mechanical Type: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**NBR**] [**EPDM**] [**FKM**] bellows and gasket. Include water slinger on shaft between motor and seal.
7. Seal, Packing Type: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.

E. Shaft Coupling: Keyed with locking collets.

F. Discharge Head: ASME B16.1, [**Class 125**] [**Class 250**] discharge flange with threaded gauge tapping. Top of discharge head shall have a registered fit to accurately locate the driver.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

G. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

In "Enclosure" Subparagraph below, coordinate type availability with equipment manufacturers.

1. Enclosure: [**Totally enclosed, fan cooled**] <**Insert enclosure type**>.

Retain first subparagraph below for premium efficiency.

2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Single**] [**Variable**]-speed motor.

Delete first subparagraph below if pump is single speed or if variable-frequency motor controller is to be provided under Section 262923 "Variable-Frequency Motor Controllers."

6. Provide integral pump motor variable-speed controller.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

7. <**Insert unique motor characteristics**>.

If Project has more than one type or configuration of separately coupled, vertically mounted, turbine centrifugal pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

H. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Minimum Static Head: <**Insert feet**>.
4. Maximum Operating Pressure: [**175 psig**] <**Insert value**>.
5. Maximum Continuous Operating Temperature: [**200 deg F**] <**Insert temperature**>.
6. Outlet Size: <**Insert NPS**>.
7. Impeller Size: <**Insert inches**>.
8. Motor Speed: <**Insert rpm**>.
9. Motor Horsepower: <**Insert value**>.
10. Electrical Characteristics:

    a. Volts: [**120**] [**240**] [**208**] [**460**] <**Insert value**> V.
    b. Phase: [**Single**] [**Three**].
    c. Hertz: 60 Hz.
    d. Full-Load Amperes: <**Insert value**> A.
    e. Minimum Circuit Ampacity: <**Insert value**> A.
    f. Maximum Overcurrent Protection: <**Insert value**> A.

2.10 WET-ROTOR PUMPS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, wet-rotor pump. Pump and motor to form an integral unit with bearings lubricated by the pumped liquid.

D. Pump Construction:

1. Body: [**100 percent lead-free bronze**] [**Type 304 stainless steel**] [**Cast iron**].
2. Impeller: [**Polypropylene**] [**Noryl**] [**Type 304 stainless steel**].
3. Pump Shaft: [**Ceramic**] [**Type 304 stainless steel**] [**Type 316 stainless steel**].
4. Bearings. Double-sintered carbon.

E. Motor: [**Single**] [**Three**] [**Variable**] speed.

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and use.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

a. Efficiency: Premium Efficiency.
b. NEMA Design: <**Insert designation**>.
c. Service Factor: <**Insert value**>.

Delete first subparagraph below if electronic motor speed control is not required.

3. Integral pump motor variable-speed control.

Delete subparagraph below if ECM is not required.

4. ECM.

If Project has more than one type or configuration of wet-rotor pump, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

F. Capacities and Characteristics:

1. Capacity: <**Insert gpm**>.
2. Total Dynamic Head: <**Insert feet**>.
3. Maximum Operating Pressure: [**150 psig**] <**Insert value**>.
4. Maximum Continuous Operating Temperature: [**225 deg F**] [**230 deg F**] <**Insert temperature**>.
5. Inlet and Outlet Size: <**Insert NPS**>.
6. Impeller Size: <**Insert inches**>.
7. Motor Speed: <**Insert rpm**>.
8. Motor Horsepower: <**Insert value**>.
9. Electrical Characteristics:

a. Volts: [**120**] <**Insert value**> V.

b. Phase: [**Single**] [**Three**].
c. Hertz: 60 Hz.
d. Full-Load Amperes: <**Insert value**> A.
e. Minimum Circuit Ampacity: <**Insert value**> A.
f. Maximum Overcurrent Protection: <**Insert value**> A.

2.11 AUTOMATIC CONDENSATE PUMP UNITS

Units in this article are complete with pump, basin, and controls and have limited applications and small capacity.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain pump units from single source from single manufacturer.

C. Description: Packaged units with corrosion-resistant pump, [**aluminum**] [**plastic**] tank with cover, and automatic controls. Collects and removes condensate from fan coil units, air handling units, condensing boilers, and similar components. Include factory- or field-installed check valve and 72-inch-minimum, electrical power cord with plug.

If Project has more than one type or configuration of automatic condensate pump unit, delete "Capacities and Characteristics" Paragraph below and schedule pumps on Drawings.

D. Capacities and Characteristics:

1. Tank Capacity: <**Insert gal**>.
2. Pump Capacity: <**Insert gpm**>.
3. Maximum Lift: <**Insert feet**>.
4. Motor Horsepower: <**Insert value**>.
5. Electrical Characteristics:

a. Volts: [**120**] <**Insert value**> V.
b. Phase: Single.
c. Hertz: 60 Hz.
d. Full-Load Amperes: <**Insert value**> A.
e. Minimum Circuit Ampacity: <**Insert value**> A.
f. Maximum Overcurrent Protection: <**Insert value**> A.

2.12 PUMP SPECIALTY FITTINGS

See the Evaluations for cautions about pump specialty fittings. In this article, retain ductile-iron body for 300-psig (2060-kPa) pressure rating; retain stainless steel strainer for condenser water usage.

A. Suction Diffuser:

1. Angle pattern.
2. [**175-psig**] [**300-psig**] pressure rating, [**cast**] [**ductile**]-iron body and end cap, pump-inlet fitting.

3. Bronze 16-mesh wire startup and [**bronze**] [**Type 304 stainless steel**] permanent strainers with 3/16-inch.
4. [**Bronze**] [**Carbon steel**] [**Type 304 stainless steel**] straightening vanes.
5. Drain plug.
6. Factory-fabricated support.

B. Triple-Duty Valve:

1. Angle or straight pattern.
2. [**175-psig**] [**300-psig**] pressure rating, [**cast**] [**ductile**]-iron body, pump-discharge fitting.
3. Valve with multi-turn stem and memory stop to allow valve to be returned to its original position after shutoff.
4. Brass valve disc with EPDM rubber seat.
5. Type 304 stainless steel valve stem.
6. Drain plug and bronze-fitted shutoff, balancing, and check valve features.
7. Brass gauge ports with integral check valve and orifice for flow measurement.

2.13 INTEGRAL PUMP MOTOR VARIABLE-SPEED CONTROLLERS

A. Where specified or scheduled, provide pumps with an integral pump motor speed controller.

1. Motor: Operates as constant- or variable-speed pump with speed regulated by an integrated variable-speed drive.
2. Integrated Pump Controller: Supports direct communication with the building management system (BMS) with built-in support for the following protocols: [**Modbus RTU**] [**BACnet? MS/TP**] [**Metasys N2**].
3. Commissioning and pump set up access to pump controls via the following:

    a. A web interface (data exchange).
    b. A user interface located on the face of speed controller to adjust modes and mode values.
    c. An electronic display that reads real-time mode set values, flow, head, speed, and power and that locks out unauthorized adjustment of pump.

4. Provide electronics with "Auto" as factory default but slope of the proportional curve will automatically match the required system curve, constant pressure control (delta-p/c), variable differential pressure control (delta-p/v), constant curve duty (uncontrolled pump), and rpm regulation. RPM (speed) regulation can be accomplished by the following:

    a. Manual (via user interface or HTML).
    b. Remote via 0 to 10 V dc.
    c. Data protocol communications with the BMS.

5. Pump Electronics: Standard with multiple digital inputs and one external digital output to be available for additional mechanical room control and pump status monitoring.
6. Controller: Mounted on or adjacent to the motor. Provide enclosure rated to UL Type 12.
7. Electronically Protected Pumps: Rated for continuous duty and with built-in startup circuit. Provide overcurrent, line surge and current limit protection, thermal monitoring, heat sink status and over temperature protection.

8. Pump capable of being monitored continuously via integrated Internet link.
9. Integrated pump controller system to have the following features:

   a. Controller software shall be capable of sensorless control in variable-volume systems without need for pump-mounted (internal/external) or remotely mounted differential pressure sensor.
   b. Integrated Pump Controller Sensorless Control: Operates under Quadratic Pressure Control (QPC) to ensure that head reduction with reducing flow conforms to quadratic control curve.
   c. Controller:

      1) Minimum head of 40 percent of design duty head.
      2) User-adjustable control mode settings and minimum/maximum head set points using built-in programming interface.

   d. Controller Integrated Control Software:

      1) Capable of controlling pump performance for non-overloading power at every point of operation.
      2) Capable of maintaining flow rate data.

2.14 ELECTRONICALLY COMMUTATED MOTOR (ECM)

A. Provide pumps so they are specified or scheduled with ECM.

1. Synchronous, constant torque, ECM with permanent magnet rotor. Rotor magnets to be time-stable, nontoxic ceramic magnets (Sr-Fe).
2. Driven by a frequency converter with an integrated power factor correction filter. Conventional induction motors will not be acceptable.
3. Each motor with an integrated variable-frequency drive, tested as one unit by manufacturer.
4. Motor speed adjustable over full range from 0 rpm to maximum scheduled speed.
5. Variable motor speed to be controlled by a 0- to 10 V-dc or 4- to 20-mA input.
6. Integrated motor protection verified by UL to protect the pump against over-/undervoltage, overtemperature of motor and/or electronics, overcurrent, locked rotor, and dry run (no-load condition).

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

Retain first two paragraphs below if required.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.

C. Examine foundations and inertia bases for suitable conditions where pumps will be installed.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PUMP INSTALLATION

In first paragraph below, retain "HI 1.4" option for centrifugal pumps and "HI 2.4" option for vertically mounted, turbine centrifugal pumps.

A. Comply with [**HI 1.4**] [**and**] [**HI 2.4**].

B. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.

C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.

D. Automatic Condensate Pump Units: Install units for collecting condensate and extend to open drain.

E. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

1. Install base-mounted pumps on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

Retain one of two subparagraphs below if vibration isolation is required. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device type and minimum deflection in supported equipment schedule on Drawings.

2. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

Retain "Equipment Mounting" Paragraph below for in-line pumps suspended from structure.

F. Equipment Mounting: Install in-line pumps with continuous-thread hanger rods and [**elastomeric hangers**] [**spring hangers**] [**spring hangers with vertical-limit stop**] of size required to support weight of in-line pumps.

1. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
2. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

3.3 ALIGNMENT

Retain this article only for separately coupled, end- and double-suction centrifugal pumps.

Retain one of first two paragraphs below.

A. Engage a factory-authorized service representative to perform alignment service.

B. Perform alignment service. When required by manufacturer to maintain warranty coverage, engage a factory-authorized service representative to perform it.

C. Comply with requirements in HI standards for alignment of pump and motor shaft. Add shims to the motor feet and bolt motor to base frame. Do not use grout between motor feet and base frame.

D. Comply with pump and coupling manufacturers' written instructions.

E. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.4 PIPING CONNECTIONS

Coordinate piping installations and specialty arrangements with Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

A. Comply with requirements for piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to pump, allow space for service and maintenance.

C. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.

E. Install [**check, shutoff, and throttling valves**] [**check valve and throttling valve with memory stop**] [**triple-duty valve**] on discharge side of pumps.

F. Install [**Y-type strainer**] [**suction diffuser**] and shutoff valve on suction side of pumps.

1. Use startup strainer for initial system startup. Install permanent strainer element before turnover of system to Owner.

G. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

H. Install pressure gauges on pump suction and discharge or at integral pressure-gauge tapping, or install single gauge with multiple-input selector valve.

Retain paragraph below for automatic condensate pump units.

Provide detail of condensate pump piping inlet and drain on Drawings. Coordinate with plumbing design.

I. Install check valve on each condensate pump unit discharge unless unit has a factory-installed check valve.

3.5 ELECTRICAL CONNECTIONS

A. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

C. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

Retain one of two subparagraphs below. First subparagraph cross-references Section 260553 "Identification for Electrical Systems" and should be retained for consistent electrical identification. Second subparagraph is an abbreviated version of product specified in Section 260553 "Identification for Electrical Systems."

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.6 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.7 STARTUP SERVICE

A. [**Engage a factory-authorized service representative to perform**] [**Perform**] startup service.

1. Complete installation and startup checks in accordance with manufacturer's written instructions.
2. Check piping connections for tightness.
3. Clean strainers on suction piping. Use startup strainer for initial startup.
4. Perform the following startup checks for each pump before starting:

   a. Verify bearing lubrication.

b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
c. Verify that pump is rotating in correct direction.

5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.
6. Start motor.
7. Open discharge valve slowly.

3.8 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," or "Perform tests and inspections" Paragraph below. Retain first option in first paragraph if Owner will hire an independent testing agency.

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform tests and inspections" Paragraph below to require Contractor to perform tests and inspections and retain option to require Contractor to arrange for the assistance of a factory-authorized service agent.

C. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

D. Hydronic pumps will be considered defective if they do not pass tests and inspections.

E. Prepare test and inspection reports.

3.9 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

END OF SECTION 232123

SECTION 232300 - REFRIGERANT PIPING

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

Verify with equipment specifications refrigeration components that are supplied and edit this Section as needed.

1.2 SUMMARY

A. Section Includes:

1. Refrigerant pipes and fittings.
2. Refrigerant piping valves and specialties.
3. Refrigerants.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of valve, refrigerant piping, and piping specialty.

1. Include pressure drop, based on manufacturer's test data, for the following:

a. Thermostatic expansion valves.
b. Solenoid valves.
c. Hot-gas bypass valves.
d. Filter dryers.
e. Strainers.
f. Pressure-regulating valves.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for HVAC units.>

C. Shop Drawings:

Retain one of first two subparagraphs below. Retain first if Drawings indicate pipe size and layout; retain second to have Contractor size and design refrigeration piping.

1. Show layout of refrigerant piping and specialties, including pipe, tube, and fitting sizes; flow capacities; valve arrangements and locations; slopes of horizontal runs; oil traps; double risers; wall and floor penetrations; and equipment connection details.
2. Show piping size and piping layout, including oil traps, double risers, specialties, and pipe and tube sizes to accommodate, as a minimum, equipment provided, elevation difference between compressor and evaporator, and length of piping to ensure proper operation and compliance with warranties of connected equipment.
3. Show interface and spatial relationships between piping and equipment.
4. Shop Drawing Scale: [**1/4 inch equals 1 foot**] <**Insert value**>.

1.4 INFORMATIONAL SUBMITTALS

Retain "Welding certificates" Paragraph below if retaining "Welding Qualifications" Paragraph in "Quality Assurance" Article.

A. Welding certificates.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For refrigerant valves and piping specialties to include in maintenance manuals.

1.6 QUALITY ASSURANCE

Retain "Welding Qualifications" Paragraph below if shop or field welding is required. If retaining, also retain "Welding certificates" Paragraph in "Informational Submittals" Article.

A. Welding Qualifications: Qualify procedures and personnel according to 2010 ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

B. Comply with ASHRAE 15, "Safety Code for Refrigeration Systems."

C. Comply with ASME B31.5, "Refrigeration Piping and Heat Transfer Components."

1.7 PRODUCT STORAGE AND HANDLING

A. Store piping with end caps in place to ensure that piping interior and exterior are clean when installed.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

If more than one type of refrigerant is required for Project, retain applicable paragraphs below and indicate on Drawings which piping circuit requires which refrigerant.

A. Line Test Pressure for Refrigerant R-134a:

1. Suction Lines for Air-Conditioning Applications: 115 psig.
2. Suction Lines for Heat-Pump Applications: 225 psig.
3. Hot-Gas and Liquid Lines: 225 psig.

B. Line Test Pressure for Refrigerant R-407C:

1. Suction Lines for Air-Conditioning Applications: 230 psig.
2. Suction Lines for Heat-Pump Applications: 380 psig.
3. Hot-Gas and Liquid Lines: 380 psig.

C. Line Test Pressure for Refrigerant R-410A:

1. Suction Lines for Air-Conditioning Applications: 300 psig.
2. Suction Lines for Heat-Pump Applications: 535 psig.
3. Hot-Gas and Liquid Lines: 535 psig.

Coordinate first two articles below with piping application articles in Part 3. See "Writing Guide" Article in the Evaluations. Materials included in this Section are examples listed in the 2008 ASHRAE HANDBOOK - "HVAC Systems and Equipment" (Ch. 45, "Pipes, Tubes, and Fittings").

2.2 COPPER TUBE AND FITTINGS

A. Copper Tube: [**ASTM B 88, Type K or L**] [**ASTM B 280, Type ACR**].

B. Wrought-Copper Fittings: ASME B16.22.

C. Wrought-Copper Unions: ASME B16.22.

See the Evaluations for discussions of solder and brazing materials.

D. Solder Filler Metals: ASTM B 32. Use 95-5 tin antimony or alloy HB solder to join copper socket fittings on copper pipe.

E. Brazing Filler Metals: AWS A5.8/A5.8M.

F. Flexible Connectors:

1. Body: Tin-bronze bellows with woven, flexible, tinned-bronze-wire-reinforced protective jacket.
2. End Connections: Socket ends.
3. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.
4. Working Pressure Rating: Factory test at minimum 500 psig.
5. Maximum Operating Temperature: 250 deg F.

G. Copper Pressure-Seal Fittings for Refrigerant Piping:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Standard: UL 207; certified by UL for field installation. Certification as a UL-recognized component alone is unacceptable.
3. Housing: Copper.
4. O-Rings: HNBR or compatible with specific refrigerant.
5. Tools: Manufacturer's approved special tools.
6. Minimum Rated Pressure: 700 psig.

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; type, grade, and wall thickness as selected in piping application articles.

B. Wrought-Steel Fittings: ASTM A 234/A 234M, for welded joints.

C. Steel Flanges and Flanged Fittings: ASME B16.5, steel, including bolts, nuts, and gaskets, bevel-welded end connection, and raised face.

D. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

E. Flanged Unions:

1. Body: Forged-steel flanges for NPS 1 to NPS 1-1/2 and ductile iron for NPS 2 to NPS 3. Apply rust-resistant finish at factory.
2. Gasket: Fiber asbestos free.
3. Fasteners: Four plated-steel bolts, with silicon bronze nuts. Apply rust-resistant finish at factory.
4. End Connections: Brass tailpiece adapters for solder-end connections to copper tubing.
5. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.
6. Pressure Rating: Factory test at minimum 400 psig.
7. Maximum Operating Temperature: 330 deg F.

F. Flexible Connectors:

1. Body: Stainless-steel bellows with woven, flexible, stainless-steel-wire-reinforced protective jacket.
2. End Connections:

   a. NPS 2 and Smaller: With threaded-end connections.
   b. NPS 2-1/2 and Larger: With flanged-end connections.

3. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.
4. Pressure Rating: Factory test at minimum 500 psig.
5. Maximum Operating Temperature: 250 deg F.

2.4 VALVES AND SPECIALTIES

A. Diaphragm Packless Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body and Bonnet: Forged brass or cast bronze; globe design with straight-through or angle pattern.
3. Diaphragm: Phosphor bronze and stainless steel with stainless-steel spring.
4. Operator: Rising stem and hand wheel.
5. Seat: Nylon.
6. End Connections: Socket, union, or flanged.
7. Working Pressure Rating: 500 psig.
8. Maximum Operating Temperature: 275 deg F.

B. Packed-Angle Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body and Bonnet: Forged brass or cast bronze.
3. Packing: Molded stem, back seating, and replaceable under pressure.
4. Operator: Rising stem.

5. Seat: Nonrotating, self-aligning polytetrafluoroethylene.
6. Seal Cap: Forged-brass or valox hex cap.
7. End Connections: Socket, union, threaded, or flanged.
8. Working Pressure Rating: 500 psig.
9. Maximum Operating Temperature: 275 deg F.

C. Check Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Ductile iron, forged brass, or cast bronze; globe pattern.
3. Bonnet: Bolted ductile iron, forged brass, or cast bronze; or brass hex plug.
4. Piston: Removable polytetrafluoroethylene seat.
5. Closing Spring: Stainless steel.

Retain "Manual Opening Stem" Subparagraph below for optional manual opening feature.

6. Manual Opening Stem: Seal cap, plated-steel stem, and graphite seal.
7. End Connections: Socket, union, threaded, or flanged.
8. Maximum Opening Pressure: 0.50 psig.
9. Working Pressure Rating: 500 psig.
10. Maximum Operating Temperature: 275 deg F.

D. Service Valves:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Forged brass with brass cap including key end to remove core.
3. Core: Removable ball-type check valve with stainless-steel spring.
4. Seat: Polytetrafluoroethylene.
5. End Connections: Copper spring.
6. Working Pressure Rating: 500 psig.

Solenoid valves in "Solenoid Valves" Paragraph below are made normally closed or normally open. Normally closed are direct acting and pilot operated. Holding coils are available in several voltages.

E. Solenoid Valves: Comply with AHRI 760 and UL 429; listed and labeled by a National Recognized Testing Laboratory (NRTL).

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body and Bonnet: Plated steel.
3. Solenoid Tube, Plunger, Closing Spring, and Seat Orifice: Stainless steel.
4. Seat: Polytetrafluoroethylene.
5. End Connections: Threaded.
6. Electrical: Molded, watertight coil in NEMA 250 enclosure of type required by location with 1/2-inch conduit adapter, and [**24**] [**115**] [**208**]-V ac coil.
7. Working Pressure Rating: 400 psig.
8. Maximum Operating Temperature: 240 deg F.

Retain "Safety Relief Valves" Paragraph below for optional manual opening feature.

F. Safety Relief Valves: Comply with 2010 ASME Boiler and Pressure Vessel Code; listed and labeled by an NRTL.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body and Bonnet: Ductile iron and steel, with neoprene O-ring seal.
3. Piston, Closing Spring, and Seat Insert: Stainless steel.
4. Seat: Polytetrafluoroethylene.
5. End Connections: Threaded.
6. Working Pressure Rating: 400 psig.
7. Maximum Operating Temperature: 240 deg F.

G. Thermostatic Expansion Valves: Comply with AHRI 750.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body, Bonnet, and Seal Cap: Forged brass or steel.
3. Diaphragm, Piston, Closing Spring, and Seat Insert: Stainless steel.
4. Packing and Gaskets: Non-asbestos.
5. Capillary and Bulb: Copper tubing filled with refrigerant charge.
6. Suction Temperature: [**40 deg F**] <**Insert temperature**>.
7. Superheat: [**Adjustable**] [**Nonadjustable**].
8. Reverse-flow option (for heat-pump applications).
9. End Connections: Socket, flare, or threaded union.
10. Working Pressure Rating: [**700 psig**] [**450 psig**] <**Insert value**>.

H. Hot-Gas Bypass Valves: Comply with UL 429; listed and labeled by an NRTL.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body, Bonnet, and Seal Cap: Ductile iron or steel.
3. Diaphragm, Piston, Closing Spring, and Seat Insert: Stainless steel.
4. Packing and Gaskets: Non-asbestos.
5. Solenoid Tube, Plunger, Closing Spring, and Seat Orifice: Stainless steel.
6. Seat: Polytetrafluoroethylene.
7. Equalizer: [**Internal**] [**External**].
8. Electrical: Molded, watertight coil in NEMA 250 enclosure of type required by location with 1/2-inch conduit adapter and [**24**] [**115**] [**208**]-V ac coil.
9. End Connections: Socket.
10. Set Pressure: <**Insert psig**>.
11. Throttling Range: Maximum 5 psig.
12. Working Pressure Rating: 500 psig.
13. Maximum Operating Temperature: 240 deg F.

I. Straight-Type Strainers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Welded steel with corrosion-resistant coating.
3. Screen: 100-mesh stainless steel.
4. End Connections: Socket or flare.
5. Working Pressure Rating: 500 psig.
6. Maximum Operating Temperature: 275 deg F.

J. Angle-Type Strainers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Forged brass or cast bronze.

3. Drain Plug: Brass hex plug.
4. Screen: 100-mesh monel.
5. End Connections: Socket or flare.
6. Working Pressure Rating: 500 psig.
7. Maximum Operating Temperature: 275 deg F.

K. Moisture/Liquid Indicators:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Forged brass.
3. Window: Replaceable, clear, fused glass window with indicating element protected by filter screen.
4. Indicator: Color coded to show moisture content in parts per million (ppm).
5. Minimum Moisture Indicator Sensitivity: Indicate moisture above 60 ppm.
6. End Connections: Socket or flare.
7. Working Pressure Rating: 500 psig.
8. Maximum Operating Temperature: 240 deg F.

L. Replaceable-Core Filter Dryers: Comply with AHRI 730.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body and Cover: Painted-steel shell with ductile-iron cover, stainless-steel screws, and neoprene gaskets.
3. Filter Media: 10 micron, pleated with integral end rings; stainless-steel support.
4. Desiccant Media: Activated [**alumina**] [**charcoal**].

Retain first subparagraph below for heat pumps.

5. Designed for reverse flow (for heat-pump applications).
6. End Connections: Socket.

Retain "Access Ports" Subparagraph below for suction-line filter dryers.

7. Access Ports: NPS 1/4 connections at entering and leaving sides for pressure differential measurement.
8. Maximum Pressure Loss: [**2 psig**] <**Insert value**>.
9. Rated Flow: <**Insert tons**>.
10. Working Pressure Rating: 500 psig.
11. Maximum Operating Temperature: 240 deg F.

M. Permanent Filter Dryers: Comply with AHRI 730.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body and Cover: Painted-steel shell.
3. Filter Media: 10 micron, pleated with integral end rings; stainless-steel support.
4. Desiccant Media: Activated [**alumina**] [**charcoal**].

Retain first subparagraph below for heat pumps.

5. Designed for reverse flow (for heat-pump applications).
6. End Connections: Socket.

Retain first subparagraph below for suction-line filter dryers.

7. Access Ports: NPS 1/4 connections at entering and leaving sides for pressure differential measurement.
8. Maximum Pressure Loss: [**2 psig**] <**Insert value**>.
9. Rated Flow: <**Insert tons**>.
10. Working Pressure Rating: 500 psig.
11. Maximum Operating Temperature: 240 deg F.

N. Mufflers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Welded steel with corrosion-resistant coating.
3. End Connections: Socket or flare.
4. Working Pressure Rating: 500 psig.
5. Maximum Operating Temperature: 275 deg F.

O. Receivers: Comply with AHRI 495.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain first subparagraph below for receivers larger than 6 inches (150 mm).

2. Comply with 2010 ASME Boiler and Pressure Vessel Code; listed and labeled by an NRTL.
3. Comply with UL 207; listed and labeled by an NRTL.
4. Body: Welded steel with corrosion-resistant coating.
5. Tappings: Inlet, outlet, liquid level indicator, and safety relief valve.
6. End Connections: Socket or threaded.
7. Working Pressure Rating: 500 psig.
8. Maximum Operating Temperature: 275 deg F.

P. Liquid Accumulators: Comply with AHRI 495.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Body: Welded steel with corrosion-resistant coating.
3. End Connections: Socket or threaded.
4. Working Pressure Rating: 500 psig.
5. Maximum Operating Temperature: 275 deg F.

2.5 REFRIGERANTS

A. ASHRAE 34, R-134a: Tetrafluoroethane.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. ASHRAE 34, R-407C: Difluoromethane/Pentafluoroethane/1,1,1,2-Tetrafluoroethane.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

C. ASHRAE 34, R-410A: Pentafluoroethane/Difluoromethane.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

PART 3 - EXECUTION

If more than one refrigerant is required for Project, retain appropriate refrigerant piping articles below and indicate refrigerant type for each piping line on Drawings.

3.1 PIPING APPLICATIONS FOR REFRIGERANT R-134a

Retain one or both suction line paragraphs below. Retain first paragraph to require all piping to be Type ACR, annealed temper. Type ACR, annealed-temper tubing is available only in sizes NPS 1-1/2 (DN 40) and smaller. Retain second paragraph if pipe sizes exceed NPS 1-1/2 (DN 40) and it is desirable to have all piping be of same tube type and joining method. Retain both paragraphs to require piping larger than NPS 1-1/2 (DN 40) to be different from Type ACR, annealed temper. Delete both paragraphs below if suction lines are part of a heat-pump installation.

A. Suction Lines [**NPS 1-1/2 and Smaller**] <**Insert pipe size range**> for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

B. Suction Lines [**NPS 4 and Smaller**] [**NPS 2 to NPS 4**] <**Insert pipe size range**> for Conventional Air-Conditioning Applications: Copper, [**Type ACR**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

Retain one of three hot-gas and liquid line paragraphs below. Retain first paragraph to require all piping to be Type ACR, annealed temper. Type ACR, annealed-temper tubing is available only in sizes NPS 1-1/2 (DN 40) and smaller. Retain second paragraph if pipe sizes exceed NPS 1-1/2 (DN 40) and it is desirable to have all piping be of same tube type and joining method. Retain third paragraph to require different tube types and joining methods for various pipe sizes.

C. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

D. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with soldered joints.

E. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]:

Retain one of first two subparagraphs below.

1. [**NPS 1-1/2 and Smaller**] <**Insert pipe size range**>: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
2. [**NPS 1-1/2 and Smaller**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
3. [**NPS 4**] <**Insert pipe size**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

Retain one of three "Safety-Relief-Valve Discharge Piping" paragraphs below. Retain first paragraph to require all safety-relief-valve discharge piping to be steel. Retain second paragraph to require all pipe sizes to be copper of same tube type and joining method. Retain third paragraph to require different tube types and joining methods for various pipe sizes.

F. Safety-Relief-Valve Discharge Piping: Schedule 40, black-steel and wrought-steel fittings with welded joints.

G. Safety-Relief-Valve Discharge Piping: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with soldered joints.

H. Safety-Relief-Valve Discharge Piping:

Retain one of first two subparagraphs below.

1. [**NPS 1-1/2 and Smaller**] <**Insert pipe size range**>: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
2. [**NPS 1-1/2 and Smaller**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
3. [**NPS 4**] <**Insert pipe size**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

3.2 PIPING APPLICATIONS FOR REFRIGERANT R-407C

Retain one or both suction line paragraphs below. Retain first paragraph to require all piping to be Type ACR, annealed temper. Type ACR, annealed-temper tubing is available only in sizes NPS 1-1/2 (DN 40) and smaller. Retain second paragraph if pipe sizes exceed NPS 1-1/2 (DN 40) and it is desirable to have all piping be of same tube type and joining method. Retain both paragraphs to require piping larger than NPS 1-1/2 (DN 40) to be different from Type ACR, annealed temper. Delete both paragraphs if suction lines are part of a heat-pump installation.

A. Suction Lines [**NPS 1-1/2 and Smaller**] <**Insert pipe size range**> for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

B. Suction Lines [**NPS 4 and Smaller**] [**NPS 2 to NPS 4**] <**Insert pipe size range**> for Conventional Air-Conditioning Applications: Copper, [**Type ACR**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

Retain one of three hot-gas and liquid line paragraphs below. Retain first paragraph to require all piping to be Type ACR, annealed temper. Type ACR, annealed-temper tubing is available only in sizes NPS 1-1/2 (DN 40) and smaller; however, brazed ACR can withstand pressure of this service only up to NPS 1 (DN 25). Retain second paragraph if pipe sizes exceed NPS 1-1/2 (DN 40) and it is desirable to have all piping be of same tube type and joining method. Retain third paragraph to require different tube types and joining methods for various pipe sizes.

C. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

D. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with soldered joints.

E. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]:

Retain one of first two subparagraphs below.

1. [**NPS 1 and Smaller**] <**Insert pipe size range**>: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
2. [**NPS 1 and Smaller**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
3. [**NPS 1-1/4 to NPS 2**] <**Insert pipe size range**>: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
4. [**NPS 4**] <**Insert pipe size**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with soldered joints.

Retain one of three "Safety-Relief-Valve Discharge Piping" paragraphs below. Retain first paragraph to require all safety-relief-valve discharge piping to be steel. Retain second paragraph to require all pipe sizes to be copper of same tube type and joining method. Retain third paragraph to require different tubes type and joining methods for various pipe sizes.

F. Safety-Relief-Valve Discharge Piping: Schedule 40, black-steel and wrought-steel fittings with welded joints.

G. Safety-Relief-Valve Discharge Piping: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with soldered joints.

H. Safety-Relief-Valve Discharge Piping:

Retain one of first two subparagraphs below.

1. [**NPS 1 and Smaller**] <**Insert pipe size range**>: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
2. [**NPS 1 and Smaller**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
3. [**NPS 1-1/4 to NPS 2**] <**Insert pipe size range**>: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
4. [**NPS 4**] <**Insert pipe size**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with soldered joints.

3.3 PIPING APPLICATIONS FOR REFRIGERANT R-410A

Retain one of three suction line paragraphs below. Retain first paragraph to require all piping to be Type ACR, annealed temper. Type ACR, annealed temper tubing is only available in sizes NPS 1-1/2 (DN 40) and smaller. Retain second or third paragraph if pipe sizes exceed NPS 1-1/2 (DN 40) and it is desirable to have all piping be of same tube type and joining method. Retain second and third paragraphs to require piping larger than NPS 1-1/2 (DN 40) to be different from Type ACR, annealed temper. Delete all three paragraphs if suction lines are part of a heat-pump installation.

A. Suction Lines [**NPS 1-1/2 and Smaller**] <**Insert pipe size range**> for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

B. Suction Lines [**NPS 3-1/2 and Smaller**] [**NPS 2 to NPS 3-1/2**] <**Insert pipe size range**> for Conventional Air-Conditioning Applications: Copper, [**Type ACR**] [**Type L**], drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

C. Suction Lines [**NPS 4 and Smaller**] <**Insert pipe size range**> for Conventional Air-Conditioning Applications: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with soldered joints.

Retain one or more of six hot-gas and liquid line paragraphs below. Each material and each joining method is limited by the pressure rating on the resulting material and joining methods. See Test Pressures for Various Refrigerants - psig (kPa) Table in the Evaluations for pressure-rating limitations. Retain first paragraph if tubing is not larger than NPS 5/8 (DN 18) and it is desirable to have all piping be of same tube type and joining method.

D. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]: Copper, [**Type ACR**] [**Type L**], annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

Retain first paragraph below if tubing is not larger than NPS 1 (DN 25) and it is desirable to have all piping be of same tube type and joining method.

E. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

Retain first paragraph below if tubing is not larger than NPS 1-1/4 (DN 32) and it is desirable to have all piping be of same tube type and joining method.

F. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.

Retain first paragraph below if tubing is not larger than NPS 2 (DN 50) and it is desirable to have all piping be of same tube type and joining method.

G. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.

Retain first paragraph below to require different tube type and joining methods for various pipe sizes.

H. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**]:

1. [**NPS 5/8 and Smaller**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type L**], annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

2. [**NPS 3/4 to NPS 1 and Smaller**] <**Insert pipe size range**>: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
3. [**NPS 1-1/4 and Smaller**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.
4. [**NPS 1-1/2 to NPS 2**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.

Retain first paragraph below if required pipe sizes exceed copper pipe sizes in paragraph above.

I. Hot-Gas and Liquid Lines[**, and Suction Lines for Heat-Pump Applications**] [**NPS 2 to NPS 4**] <**Insert pipe size range**>: Schedule 40, black-steel and wrought-steel fittings with welded joints.

Retain one of six "Safety-Relief-Valve Discharge Piping" paragraphs below. Each material and each joining method is limited by the pressure rating on the resulting material and joining methods. See Tests Pressures for Various Refrigerants - psig (kPa) Table in the Evaluations for pressure-rating limitations. Retain first paragraph if tubing is not larger than NPS 5/8 (DN 18) and it is desirable to have all piping be of same tube type and joining method.

J. Safety-Relief-Valve Discharge Piping: Copper, [**Type ACR**] [**Type L**], annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

Retain first paragraph below if tubing is not larger than NPS 1 (DN 25) and it is desirable to have all piping be of same tube type and joining method.

K. Safety-Relief-Valve Discharge Piping: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

Retain first paragraph below if tubing is not larger than NPS 1-1/4 (DN 32) and it is desirable to have all piping be of same tube type and joining method.

L. Safety-Relief-Valve Discharge Piping: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.

Retain first paragraph below if tubing is not larger than NPS 2 (DN 50) and it is desirable to have all piping be of same tube type and joining method.

M. Safety-Relief-Valve Discharge Piping: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.

Retain first paragraph below to require different tube types and joining methods for various pipe sizes.

N. Safety-Relief-Valve Discharge Piping:

1. [**NPS 5/8 and Smaller**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type L**], annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.
2. [**NPS 3/4 to NPS 1 and Smaller**] <**Insert pipe size range**>: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with [**brazed**] [**or**] [**soldered**] joints.

3. [**NPS 1-1/4 and Smaller**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.
4. [**NPS 1-1/2 to NPS 2**] <**Insert pipe size range**>: Copper, [**Type ACR**] [**Type K**] [**Type L**], drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.

Retain paragraph below if required pipe sizes exceed copper pipe sizes in "Safety-Relief-Valve Discharge Piping" Paragraph above.

O. Safety-Relief-Valve Discharge Piping [**NPS 2 to NPS 4**] <**Insert pipe size range**>: Schedule 40, black-steel and wrought-steel fittings with welded joints.

3.4 VALVE AND SPECIALTY APPLICATIONS

Delete first paragraph below if valves are specified in Section 236200 "Packaged Compressor and Condenser Units."

A. Install [**diaphragm packless**] [**packed-angle**] valves in suction and discharge lines of compressor.

B. Install service valves for gage taps at inlet and outlet of hot-gas bypass valves and strainers if they are not an integral part of valves and strainers.

Retain first paragraph below if suction line will be exposed to air temperatures less than 75 deg F (24 deg C) during compressor operation.

C. Install a check valve at the compressor discharge and a liquid accumulator at the compressor suction connection.

D. Except as otherwise indicated, install [**diaphragm packless**] [**packed-angle**] valves on inlet and outlet side of filter dryers.

Retain first paragraph below only for systems that cannot be shut down for a short time to replace the filter dryer.

E. Install a full-size, three-valve bypass around filter dryers.

Retain first paragraph below for solenoid valves on systems with multiple thermostatic expansion valves. Retain for hot-gas bypass valve if not integral to the valve.

F. Install solenoid valves upstream from each expansion valve and hot-gas bypass valve. Install solenoid valves in horizontal lines with coil at top.

G. Install thermostatic expansion valves as close as possible to distributors on evaporators.

1. Install valve so diaphragm case is warmer than bulb.

In first subparagraph below, verify proper location for bulb with valve manufacturer.

2. Secure bulb to clean, straight, horizontal section of suction line using two bulb straps. Do not mount bulb in a trap or at bottom of the line.

3. If external equalizer lines are required, make connection where it will reflect suction-line pressure at bulb location.

H. Install safety relief valves where required by 2010 ASME Boiler and Pressure Vessel Code. Pipe safety-relief-valve discharge line to outside according to ASHRAE 15.

I. Install moisture/liquid indicators in liquid line at the inlet of the thermostatic expansion valve or at the inlet of the evaporator coil capillary tube.

J. Install strainers upstream from and adjacent to the following unless they are furnished as an integral assembly for the device being protected:

Edit list below for equipment required for Project.

1. Solenoid valves.
2. Thermostatic expansion valves.
3. Hot-gas bypass valves.
4. Compressor.

K. Install filter dryers in liquid line between compressor and thermostatic expansion valve[**, and in the suction line at the compressor**].

Consult refrigeration equipment manufacturer to determine the need for a receiver.

L. Install receivers sized to accommodate pump-down charge.

See the Evaluations for discussion of flexible connectors.

M. Install flexible connectors at compressors.

3.5 PIPING INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems; indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Shop Drawings.

B. Install refrigerant piping according to ASHRAE 15.

C. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

F. Install piping adjacent to machines to allow service and maintenance.

G. Install piping free of sags and bends.

H. Install fittings for changes in direction and branch connections.

I. Select system components with pressure rating equal to or greater than system operating pressure.

J. Refer to Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC" for solenoid valve controllers, control wiring, and sequence of operation.

K. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.

L. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as specified in Section 083113 "Access Doors and Frames" if valves or equipment requiring maintenance is concealed behind finished surfaces.

M. Install refrigerant piping in protective conduit where installed belowground.

N. Install refrigerant piping in rigid or flexible conduit in locations where exposed to mechanical injury.

O. Slope refrigerant piping as follows:

See the Evaluations for discussion of oil entrainment. Refer to the 2010 ASHRAE HANDBOOK - "Refrigeration" for discussion of methods for managing oil entrainment in refrigerant gas and liquid.

1. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
2. Install horizontal suction lines with a uniform slope downward to compressor.

Use double-suction riser for maximum compressor efficiencies if load variation is expected.

3. Install traps and double risers to entrain oil in vertical runs.
4. Liquid lines may be installed level.

P. When brazing or soldering, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.

Retain first paragraph below for steel pipe. Review the cost of steel pipe using these procedures versus the cost of copper piping. Also consider limiting the size of the refrigerant system and its piping to avoid the use of steel pipe.

Q. Before installation of steel refrigerant piping, clean pipe and fittings using the following procedures:

1. Shot blast the interior of piping.
2. Remove coarse particles of dirt and dust by drawing a clean, lintless cloth through tubing by means of a wire or electrician's tape.
3. Draw a clean, lintless cloth saturated with trichloroethylene through the tube or pipe. Continue this procedure until cloth is not discolored by dirt.

4. Draw a clean, lintless cloth, saturated with compressor oil, squeezed dry, through the tube or pipe to remove remaining lint. Inspect tube or pipe visually for remaining dirt and lint.
5. Finally, draw a clean, dry, lintless cloth through the tube or pipe.
6. Safety-relief-valve discharge piping is not required to be cleaned but is required to be open to allow unrestricted flow.

R. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.

S. Identify refrigerant piping and valves according to Section 230553 "Identification for HVAC Piping and Equipment."

T. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

Retain first paragraph below for piping that penetrates an exterior concrete wall or concrete slab.

U. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

V. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.6 PIPE JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

Retain first paragraph below for steel pipe.

C. Fill pipe and fittings with an inert gas (nitrogen or carbon dioxide), during brazing or welding, to prevent scale formation.

D. Soldered Joints: Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook."

E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Chapter "Pipe and Tube."

1. Use Type BCuP (copper-phosphorus) alloy for joining copper socket fittings with copper pipe.
2. Use Type BAg (cadmium-free silver) alloy for joining copper with bronze or steel.

F. Threaded Joints: Thread steel pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and to restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry-seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

G. Steel pipe can be threaded, but threaded joints must be seal brazed or seal welded.

H. Welded Joints: Construct joints according to AWS D10.12M/D10.12.

I. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.7 INSTALLATION OF HANGERS AND SUPPORTS

Retain first paragraph below for projects in areas that require seismic restraints.

A. Comply with requirements for seismic restraints in Section 230548 "Vibration and Seismic Controls for HVAC."

B. Comply with Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hangers, supports, and anchor devices.

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet long.
2. Roller hangers and spring hangers for individual horizontal runs 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
4. Spring hangers to support vertical runs.
5. Copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

D. Install hangers for [**copper tubing**] [**and**] [**steel piping**], with maximum horizontal spacing and minimum rod diameters, to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

E. Support horizontal piping within [**12 inches**] <**Insert dimension**> of each fitting.

F. Support vertical runs of [**copper tubing**] [**and**] [**steel piping**] to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

3.8 FIELD QUALITY CONTROL

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

A. Perform the following tests and inspections:

1. Comply with ASME B31.5, Chapter VI.

2. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
3. Test high- and low-pressure side piping of each system separately at not less than the pressures indicated in "Performance Requirements" Article.
   a. Fill system with nitrogen to the required test pressure.
   b. System shall maintain test pressure at the manifold gage throughout duration of test.
   c. Test joints and fittings with electronic leak detector or by brushing a small amount of soap and glycerin solution over joints.
   d. Remake leaking joints using new materials, and retest until satisfactory results are achieved.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

B. Prepare test and inspection reports.

3.9 SYSTEM CHARGING

A. Charge system using the following procedures:

1. Install core in filter dryers after leak test but before evacuation.
2. Evacuate entire refrigerant system with a vacuum pump to 500 micrometers. If vacuum holds for 12 hours, system is ready for charging.
3. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
4. Charge system with a new filter-dryer core in charging line.

3.10 ADJUSTING

Retain first paragraph below for adjustable thermostatic expansion valves.

A. Adjust thermostatic expansion valve to obtain proper evaporator superheat.

B. Adjust high- and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.

C. Adjust set-point temperature of air-conditioning or chilled-water controllers to the system design temperature.

D. Perform the following adjustments before operating the refrigeration system, according to manufacturer's written instructions:

1. Open shutoff valves in condenser water circuit.
2. Verify that compressor oil level is correct.
3. Open compressor suction and discharge valves.
4. Open refrigerant valves except bypass valves that are used for other purposes.
5. Check open compressor-motor alignment and verify lubrication for motors and bearings.

E. Replace core of replaceable filter dryer after system has been adjusted and after design flow rates and pressures are established.

END OF SECTION 232300

SECTION 232500 - HVAC WATER TREATMENT

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes the following HVAC water-treatment systems:

1. Manual and automatic chemical-feed equipment and controls.
2. Ozone-generator biocide equipment and controls.
3. Stainless steel pipes and fittings.
4. UV-irradiation unit, biocide equipment, and controls.
5. Chemical-treatment test equipment.
6. Chemicals.
7. HVAC makeup-water softeners.
8. RO equipment for HVAC makeup water.

9. TDS controllers.
10. TSS controllers.
11. Water-filtration equipment.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. EEPROM: Electrically erasable, programmable read-only memory.

B. PPM: Parts per million.

C. RO: Reverse osmosis.

D. TDS: Total dissolved solids consist of salts and other materials that combine with water as a solution.

E. TSS: Total suspended solids include both organic and inorganic solids that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, and furnished specialties and accessories for the following products:

1. Bypass feeders.
2. Water meters.
3. Inhibitor injection timers.
4. pH controllers.
5. TDS controllers.
6. TSS controllers.
7. Biocide feeder timers.
8. Chemical solution tanks.
9. Injection pumps.
10. Ozone generators.
11. UV-irradiation units.
12. Chemical test equipment.
13. Chemical material safety data sheets.
14. Inhibited ethylene glycol.
15. Inhibited propylene glycol.
16. Water softeners.
17. RO units.
18. Multimedia filters.
19. Self-cleaning strainers.
20. Replaceable bag- or cartridge-type filters.
21. Centrifugal separators.

B. Shop Drawings: Pretreatment equipment and chemical- [**and ozone-generator-biocide-**] [**and UV-irradiation-biocide-**] treatment equipment, showing tanks, maintenance space required, and piping connections to HVAC systems.

1. Include plans, elevations, sections, and attachment details.
2. Include diagrams for power and control wiring.

1.5 INFORMATIONAL SUBMITTALS

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

A. Seismic Qualification Certificates: For [**chemical-treatment equipment**] [**water softeners**] [**RO equipment**] [**water-filtration units**] and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

See Section 014000 "Quality Requirements" for a definition of the term "experience."

B. Water-Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

Retain "Water-Treatment Program" Paragraph below if retaining "Maintenance Service" Article.

D. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.

E. Water Analysis: Illustrate water quality available at Project site.

Retain "Passivation Confirmation Report" Paragraph below for open systems that contain a galvanized cooling tower or an evaporative or a fluid cooler.

F. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to Architect.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For sensors, injection pumps, [**water softeners,**] [**RO equipment,**] [**water-filtration units,**] and controllers to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

See Section 014000 "Quality Requirements" for a definition of the term "experienced."

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider, capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 HVAC WATER-TREATMENT MANUFACTURERS

Retain this article to require a single-source responsibility for all water-treatment equipment and materials.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.2 PERFORMANCE REQUIREMENTS

The companies listed above supply water-treatment chemicals. They will also furnish and install all required hardware and provide a complete on-site HVAC water-treatment program.

A. Provide all hardware, chemicals, and other material necessary to maintain HVAC water quality in all systems as indicated in this Specification. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or to the environment.

B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

Desirable water-quality values differ widely, depending upon raw water conditions, piping system materials, and service conditions. Recommendations from water-treatment companies vary. Specified target values must be determined by careful consideration of all operating conditions and with the assistance of a qualified water chemistry expert.

C. Closed hydronic systems, including [**hot-water heating below 250 deg F**] [**chilled water**] [**dual-temperature water**] [**glycol heating**] [**and**] [**glycol cooling**] shall have the following water qualities:

1. pH: Maintain a value within <**Insert range**>.
2. Alkalinity: Maintain a value within <**Insert range**> mg/L as CaCO(3).
3. Steel Corrosion Inhibiters: Provide sufficient inhibitors to limit mild steel corrosion to <**Insert number**> mils per year. Maintain soluble iron concentrations at or below <**Insert value**> mg/L.
4. Yellow Metal Corrosion Inhibitor: Provide sufficient copper and brass corrosion inhibitors to limit copper corrosion to <**Insert number**> mils per year. Maintain soluble copper concentrations at or below <**Insert value**> mg/L.
5. Scale Control: Provide softened water for initial fill and makeup. [**Where softened water is not used, provide sufficient scale inhibitors to prevent formation of scale and maintain all scale-forming material in solution.**]
6. Dispersants: Provide sufficient dispersants to prevent sedimentation of fine particulate matter.
7. Microbiological Limits:

   a. Total Aerobic Plate Count: Maintain a maximum value of <**Insert number**> organisms/mL.
   b. Total Anaerobic Plate Count: Maintain a maximum value of <**Insert number**> organisms/mL.
   c. Nitrate Reducers: Maintain a maximum value of <**Insert number**> organisms/mL.
   d. Sulfate Reducers: Maintain a maximum value of <**Insert number**> organisms/mL.
   e. Iron Bacteria: Maintain a maximum value of <**Insert number**> organisms/mL.

8. <**Insert other applicable requirements**>.

D. Open hydronic systems, including [**condenser**] [**and**] [**fluid-cooler spray**] water, shall have the following water qualities:

1. pH: Maintain a value within <**Insert range**>.
2. Alkalinity: Maintain a maximum value of <**Insert range**> mg/L as CaCO(3).
3. Silica in Cooling Towers: Maintain a value no higher than <**Insert number**> mg/L.
4. Silica in Evaporative Condensers: Maintain a value no higher than <**Insert number**> mg/L.
5. Hardness in Cooling Towers: Maintain a value no higher than <**Insert value**> mg/L as CaCO(3).
6. Hardness in Evaporative Condensers: Maintain a value no higher than <**Insert value**> mg/L as CaCO(3).
7. Steel Corrosion Inhibiters: Provide sufficient inhibitors to limit mild steel corrosion to <**Insert number**> mils per year. Maintain soluble iron concentrations at or below <**Insert value**> mg/L.
8. Yellow Metal Corrosion Inhibitor: Provide sufficient copper and brass corrosion inhibitors to limit copper corrosion to <**Insert value**> mils per year. Maintain soluble copper concentrations at or below <**Insert value**> mg/L.
9. Scale Control: [**Provide softened water for initial fill and makeup.**] [**Provide sufficient scale inhibitors to prevent formation of scale and maintain all scale-forming material in solution.**]

10. Dispersants: Provide sufficient dispersants to prevent sedimentation of fine particulate matter.
11. Microbiological Limits:

    a. Total Aerobic Plate Count: Maintain a maximum value of <**Insert number**> organisms/mL.
    b. Total Anaerobic Plate Count: Maintain a maximum value of <**Insert number**> organisms/mL.
    c. Nitrate Reducers: Maintain a maximum value of <**Insert number**> organisms/mL.
    d. Sulfate Reducers: Maintain a maximum value of <**Insert number**> organisms/mL.
    e. Iron Bacteria: Maintain a maximum value of <**Insert number**> organisms/mL.

12. <**Insert other applicable requirements**>.

Retain "Passivation for Galvanized Steel" Paragraph below for cooling towers, evaporative coolers, or other equipment with galvanized-steel components, to avoid white rust. All galvanized-steel component surfaces exposed to cooling water must be properly passivated in accordance with manufacturer's instructions during initial startup. Water quality, especially pH and alkalinity, must be maintained within manufacturer's required parameters during the passivation period and during later operation to avoid serious damage to galvanized surfaces.

E. Passivation for Galvanized Steel:

1. Passivation of all galvanized-steel cooling towers and other system components must be conducted strictly in accordance with manufacturer's instructions in order to validate warranties. During the required passivation period, all water-quality parameters must be maintained in accordance with manufacturer's specifications, and all other requirements must be observed.

F. Steam Boiler and Steam Condensate:

Retain "Steam Condensate" Subparagraph below if chemical treatment is required for condensate piping system. Chemicals that carry over from boiler to treat the condensate-water piping may make steam unfit for humidification or foodservice.

1. Steam Condensate:

    a. pH: Maintain a value within <**Insert range**>.
    b. Alkalinity: Maintain a value no higher than <**Insert range**> mg/L as CaCO(3).
    c. Steel Corrosion Inhibiters: Provide sufficient inhibitors to limit mild steel corrosion to <**Insert number**> mils per year. Maintain soluble iron concentrations at or below <**Insert value**> mg/L.
    d. Yellow Metal Corrosion Inhibitor: Provide sufficient copper and brass corrosion inhibitors to limit copper corrosion to <**Insert value**> mils per year. Maintain soluble copper concentrations at or below <**Insert value**> mg/L.
    e. Ammonia: Maintain a value of <**Insert number**> mg/L.
    f. <**Insert other requirements if necessary**>.

2. Steam boiler operating at 100 psig and less shall have the following water qualities:

    a. Silica: Maintain a value no higher than <**Insert value**> mg/L as SiO(2).

b. TSS: Maintain a value no higher than <**Insert value**> mg/L.
c. TDS: Maintain a value no higher than <**Insert value**> mg/L.
d. Total Alkalinity: Maintain a value no higher than <**Insert value**> mg/L as CaCO(3).
e. pH: Maintain a value within <**Insert range**> pH.
f. <**Insert other applicable requirements**>.

2.3 MANUAL CHEMICAL-FEED EQUIPMENT

Retain this article for closed piping systems, such as chilled-water, hot-water, and dual-temperature piping.

A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Provide quarter- turn or threaded fill cap with gasket seal and diaphragm arranged to lock the top onto the feeder when exposed to system pressure in the vessel. Provide a NPS 3/4 IN quarter-turn valve on inlet and outlet.

1. Capacity: [**2 gal.**] [**5 gal.**] <**Insert value**>.
2. Minimum Working Pressure: [**125 psig**] [**175 psig**] <**Insert value**>.

2.4 AUTOMATIC CHEMICAL-FEED EQUIPMENT

Retain one or more of "Water Meter, Oscillating Piston," "Water Meter, Turbine Type, Threaded," and "Water Meter, Turbine Type, Flanged" paragraphs below. If retaining more than one paragraph, indicate on Drawings where meters are to be installed. Open systems and large closed systems, of more than 400 gpm (25 L/s), should be equipped with a meter. Coordinate type of meter signal with controllers and DDC system.

A. Water Meter, Oscillating Piston:

1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 150 psig.
4. Maximum Pressure Loss at Design Flow: 3 psig.
5. Registration: Gallons or cubic feet.
6. End Connections: Threaded.
7. [**Controls: Flow-control switch with normally open contacts, rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.**]
8. [**Provide an electronic or digital interface for flow rate indication at central workstation compatible with DDC system, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC." Low-voltage signal must be capable of transmitting 1000 feet.**]
9. [**All electrical components, devices, and accessories must be listed and labeled as defined in NFPA 70, by a qualified testing agency, and must be marked for intended location and application.**]

B. Water Meter, Turbine Type, Threaded:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 100 psig.
4. Maximum Pressure Loss at Design Flow: 3 psig.
5. Registration: Gallons or cubic feet.
6. End Connections: Threaded.
7. [**Controls: Flow-control switch with normally open contacts, rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.**]
8. [**Provide an electronic or digital interface for flow rate indication at central workstation compatible with DDC system, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC." Low-voltage signal must be capable of transmitting 1000 feet.**]
9. [**All electrical components, devices, and accessories must be listed and labeled as defined in NFPA 70, by a qualified testing agency, and must be marked for intended location and application.**]

C. Water Meter, Turbine Type, Flanged:

1. AWWA C701, turbine-type, totalization meter.
2. Body: [**Bronze**] [**Epoxy-coated cast iron**].
3. Minimum Working-Pressure Rating: 150 psig.
4. Maximum Pressure Loss at Design Flow: 3 psig.
5. Registration: Gallons or cubic feet.
6. End Connections: Flanged.
7. [**Controls: Flow-control switch with normally open contacts, rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.**]
8. [**Provide and electronic or digital interface for flow rate indication at central workstation compatible with DDC system, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC." Low-voltage signal must be capable of transmitting 1000 feet.**]
9. [**All electrical components, devices, and accessories must be listed and labeled as defined in NFPA 70, by a qualified testing agency, and must be marked for intended location and application.**]

Retain "Inhibitor Injection Timers" Paragraph below for open systems.

D. Inhibitor Injection Timers:

1. Microprocessor-based controller with digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door.[**Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. Programmable timers with infinite adjustment over full range, mounted in cabinet with hand-off-auto switches and status lights.
3. Test switch.
4. Hand-off-auto switch for chemical pump.
5. Illuminated legend to indicate feed when pump is activated.
6. Programmable lockout timer with indicator light. Lockout timer to deactivate the pump and activate alarm circuits.
7. Digital display makeup totalizer to measure amount of makeup and bleed-off water from two water meter inputs.

Retain "pH Controller" Paragraph below for open systems that require acid injection for pH control.

E. pH Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 14 units. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door.[**Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal pH indication.
5. High or low-pH-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for acid pump.
7. Internal adjustable hysteresis or deadband.

Retain "TDS Controller" Paragraph below for open systems, including steam boilers, cooling towers, and fluid coolers.

F. TDS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door.[**Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal conductance indication.
5. High- or low-conductance-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.
9. Bleed Valves:

    a. Cooling Systems: Forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.
    b. Steam Boilers: Motorized ball valve, steel body, and TFE seats and seals.

Retain "TSS Controller" Paragraph below for open systems, including steam boilers, cooling towers, and fluid coolers when TSS controller is required.

G. TSS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from 0.001 mg/L to 50 g/L. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 4X enclosure.[**Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. [**Forms of digital communication:**] [**MODBUS RS-232**] [**MODBUS RS-485**] [**Profibus DP**].
3. Digital display and touch pad for input.

4. Sensor probe adaptable to sample stream manifold.
5. High- or low-value-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.

Retain "Biocide Feeder Timer" Paragraph below for open hydronic systems, including cooling towers and fluid coolers.

H. Biocide Feeder Timer:

1. Microprocessor-based controller with digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door.[**Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]
2. 24-hour timer with 14-day skip feature to permit activation any hour of day.
3. Precision, solid-state, bleed-off lockout timer and clock-controlled biocide pump timer. Prebleed and bleed lockout timers.
4. Solid-state alternator to enable use of two formulations.
5. 24-hour display of time of day.
6. 14-day display of day of week.
7. Battery backup, so clock is not disturbed by power outages.
8. Hand-off-auto switches for biocide pumps.
9. Biocide A and Biocide B pump running indication.

I. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: [**30 gal.**] [**50 gal.**] [**120 gal.**] <**Insert value**>.

J. Chemical Solution Injection Pumps:

1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.

Motor characteristics, such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency, are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

K. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints, except ASTM A269/A269M, Type 304 stainless steel for steam boiler injection assemblies.

L. Injection Assembly:

1. Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: [**Three**] [**Two**]-piece stainless steel, as described in "Stainless Steel Pipes and Fittings" Article; selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 600 psig at 200 deg F.

2.5 OZONE-GENERATOR BIOCIDE EQUIPMENT

A. Corona discharge generator with stainless steel generating cells and transformer housed in a NEMA 250, Type 4 enclosure. Assembly shall be suitable for continuous duty. Provide site glasses to verify proper operation of generator.

B. Water-cooled generators shall be provided with cooling water at maximum [**70 deg F**] <**Insert value**> and [**35 psig**] <**Insert value**>.

C. Generator vessels exposed to system pressure shall be constructed in accordance with 2017 ASME Boiler and Pressure Vessel Code and be equipped with pressure-relief valve.

D. External air compressor or induced airflow through a cleanable prefilter supplies concentrated oxygen through a molecular sieve, with minus 62 deg F dew point to avoid the formation of nitric acid.

E. Microprocessor-based control with software in EEPROM, surge protection, high-temperature cutout, and operational status lights.[**Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."**]

F. Ozone Contactors:

1. Bubble diffusers.
2. Induction injection nozzle.
3. Injectors with static mixers.

G. Ozone Detector and Alarm Devices:

1. Detector:

   a. Sensor: Metal dioxide semiconductor.
   b. Concentration Range: [**0 to 10**] <**Insert range**> ppm.
   c. Accuracy: Plus or minus 0.01 ppm.
   d. Sensitivity: 0.01 ppm.
   e. Response Time: Maximum 10 seconds.
   f. Operating Temperature: 50 to 100 deg F.
   g. Relative Humidity: 15 to 90 percent, noncondensing over the operating temperature range.

2. Horns:

   a. Electric-vibrating-polarized type.
   b. 24-V dc, with provision for housing the operating mechanism behind a grille.
   c. Horns shall produce a sound-pressure level of 90 dBA, measured 10 feet from the horn.
   d. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

3. Visible Alarm Devices:

   a. Xenon strobe lights listed in UL 1971, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate.
   b. Rated Light Output: [**75**] [**110**] <**Insert number**> candela.
   c. Strobe Leads: Factory connected to screw terminals.

H. Self-Contained Breathing Apparatus: Open-circuit, pressure-demand compressed air includes completely assembled, portable, self-contained devices designed for hazardous breathing environment application.

1. Face Piece: EPDM or silicone rubber construction material, one-size-fits-all with double-sealing edge, stainless steel speaking diaphragm and lens retainer, five adjustable straps to hold face piece to head (two straps on each side and one on top), exhalation valve in mask, close-fitting nose piece to ensure no CO(2) buildup, and perspiration drain to avoid skin irritation and to prevent eyepiece, spectacle, and lens fogging.
2. Backplate: Orthopedically designed of [**chemical and impact-resistant, glass-fiber composite**] [**aluminum**].
3. Harness and Carrier Assembly: Large triangular back pad, backplate, and adjustable waist and shoulder straps; modular in design, detachable components, and easy to clean and maintain. Shoulder straps are padded with flame-resistant material, reinforced with stainless steel cable, and attached with T-nuts, washers, and screws.
4. Air Cylinder: [**30**] [**45**] [**60**]-minute, low-pressure, air-supply-loaded [**fiberglass**] [**aluminum**] [**steel**] cylinders fitted with quick-fill assembly for refilling and air transfer.
5. Wall-Mounting Cabinet: Leakproof, corrosion-resistant, clear, plastic case.
6. Tested and Certified: By the National Institute for Occupational Safety and Health and by the Mine Safety and Health Administration, in accordance with 42 CFR 84, Subpart H.

2.6 STAINLESS STEEL PIPES AND FITTINGS

A. Stainless Steel Tubing: Comply with ASTM A269/A269M, Type 316.

B. Stainless Steel Fittings: Comply with ASTM A815/A815M, Type 316, Grade WP-S.

Retain "Two-Piece, Full-Port, Stainless Steel Ball Valves," or "Three-Piece, Full-Port, Stainless Steel Ball Valves" Paragraph below.

C. Two-Piece, Full-Port, Stainless Steel Ball Valves: ASTM A351/A351M, Type 316 stainless steel body; ASTM A276/A276M, Type 316 stainless steel stem and vented ball, carbon-filled

TFE seats, threaded body design with adjustable stem packing, threaded ends, and 250-psig steam working pressure and 600-psig cold working pressure ratings.

D. Three-Piece, Full-Port, Stainless Steel Ball Valves: ASTM A351/A351M, Type 316 stainless steel body; ASTM A276/A276M, Type 316 stainless steel stem and vented ball, threaded body design with adjustable stem packing, threaded ends, and 150-psig steam working pressure and 600-psig cold working pressure rating.

2.7 UV BIOCIDE EQUIPMENT

A. Target Irradiation: Minimum [**5,000 microWxs/sq. cm**] <**Insert value**>.

B. Light Source Vessels:

1. ASTM A666, Type 304 stainless steel.
2. Construct for minimum [**150 psig**] <**Insert value**> at [**150 deg F**] <**Insert value**> in accordance with ASME Boiler and Pressure Vessel Code, and equipped with pressure-relief valve.
3. Light Source Sleeve: Quartz, with EPDM O-ring seals.
4. Light Source: Replaceable UV lamp producing minimum target irradiation of 254-nm wavelength light.

C. Controls: Interlock with pumps to operate when water is circulating.

2.8 CHEMICAL-TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounted cabinet for testing pH, TSS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers; and oxidizing biocide test for open cooling systems.

Retain "Sample Cooler" Paragraph below for steam boilers.

B. Sample Cooler:

1. Tube: Sample.

    a. Size: NPS 1/4 tubing.
    b. Material: ASTM A666, Type 316 stainless steel.
    c. Pressure Rating: Minimum 2000 psig.
    d. Temperature Rating: Minimum 850 deg F.

2. Shell: Cooling water.

    a. Material: ASTM A666, Type 304 stainless steel.
    b. Pressure Rating: Minimum 250 psig.
    c. Temperature Rating: Minimum 450 deg F.

3. Capacities and Characteristics:

    a. Tube: Sample.

1) Flow Rate: [**0.25 gpm**] <**Insert value**>.
2) Entering Temperature: [**400 deg F**] <**Insert value**>.
3) Leaving Temperature: [**88 deg F**] <**Insert value**>.
4) Pressure Loss: [**6.5 psig**] <**Insert value**>.

b. Shell: Cooling water.

1) Flow Rate: [**3 gpm**] <**Insert value**>.
2) Entering Temperature: [**70 deg F**] <**Insert value**>.
3) Pressure Loss: [**1.0 psig**] <**Insert value**>.

C. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

1. [**Two**] <**Insert number**>-station rack for closed-loop systems.
2. [**Four**] <**Insert number**>-station rack for open-loop systems.

2.9 CHEMICALS

Revise this article to suit local conditions and recommendations of chemical-treatment manufacturer.

A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment and that can attain water quality specified in "Performance Requirements" Article.

B. Chemicals for direct steam injection humidification and for steam used in direct contact with food to be FDA approved and safe for these uses.

Retain "Water Softener Chemicals" Paragraph below for water softeners.

C. Water Softener Chemicals:

1. Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range, with good resistance to bead fracture from attrition or shock. Resin exchange capacity minimum <**Insert grains/cu. ft.** > of calcium carbonate of resin when regenerated with <**Insert lb**> of salt.
2. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are unacceptable.

2.10 INHIBITED ETHYLENE GLYCOL AND PROPYLENE GLYCOL

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Before retaining "Inhibited Ethylene Glycol" Paragraph below, due to toxicity concerns, verify if ethylene glycol is permitted for use in specific application by locally enforced codes and authorities having jurisdiction.

B. Inhibited Ethylene Glycol:

1. Ethylene glycol with inhibitor additive, to provide freeze protection for heat-transfer fluid and corrosion protection for carbon-steel, brass, copper, stainless steel, and cast-iron piping and fittings.
2. Inhibitor creates a passive layer on all surfaces that contact ethylene glycol to prevent corrosion by stabilizing fluid pH, to compensate for acids formed from glycol degradation.
3. pH value shall be maintained between <**Insert range**>, with reserve alkalinity greater than <**Insert number**> mL.
4. Operating Temperature Range: [**minus 60 deg F to 250 deg F**] <**Insert range**>
5. Concentrated inhibited ethylene glycol is to be 95.5 percent ethylene glycol by weight and 4.5 percent performance additives.
6. Concentrated inhibited ethylene glycol is mixed with water in proper proportion specified by the manufacturer to provide freeze protection to [**minus 20 deg F**]. Premixed heat-transfer fluid may be used, or glycol/water mixture may be prepared at time of installation. Use only deionized water for mixing.
7. Provide only ethylene glycol that is specifically blended for HVAC application. Automotive-type antifreeze is unacceptable.

C. Inhibited Propylene Glycol:

1. Propylene glycol with inhibitor additive, to provide freeze protection for heat-transfer fluid and corrosion protection for carbon-steel, brass, copper, stainless steel, and cast-iron piping and fittings.
2. Inhibitor creates a passive layer on all surfaces that contact propylene glycol to prevent corrosion and stabilizes fluid pH, to compensate for acids formed from glycol degradation.
3. pH value shall be maintained between <**Insert range**>, with reserve alkalinity greater than <**Insert number**> mL.
4. Operating Temperature Range: [**minus 50 deg F to 250 deg F**] <**Insert range**>
5. Concentrated inhibited propylene glycol is to be 95.5 percent propylene glycol by weight and 4.5 percent performance additives.
6. Concentrated inhibited propylene glycol is mixed with water in proper proportion specified by the manufacturer to provide freeze protection to [**minus 20 deg F**] <**Insert number**>. Premixed heat-transfer fluid may be used, or glycol/water mixture may be prepared at the time of installation. Use only deionized water for mixing.
7. Provide only propylene glycol that is specifically blended for HVAC application. Automotive-type antifreeze is unacceptable.

2.11 HVAC MAKEUP-WATER SOFTENER

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Description: Twin mineral tanks and one brine tank, factory mounted on skid.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain first paragraph below for projects in seismic areas; if retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

D. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event, when tank supports are anchored to building structure as recommended in writing by manufacturer.

E. Mineral Tanks:

Retain first subparagraph below to require steel or stainless steel tanks to be ASME labeled; delete for non-code construction.

1. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

Retain first subparagraph below to require fiber-reinforced plastic tanks to be ASME labeled; delete for non-code construction.

2. Fabricate and label fiber-reinforced plastic filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.

First option in "Pressure Rating" Subparagraph below is usual minimum pressure rating; use higher rating if required.

3. Pressure Rating: [**100 psig**] [**125 psig**] [**150 psig**] <**Insert value**> minimum.
4. Wetted Components: Suitable for water temperatures from [**40 to at least 100 deg F**] <**Insert range**>.
5. Freeboard: 50 percent minimum, for backwash expansion above the normal resin bed level.
6. Support Legs or Skirt: Constructed of structural steel, welded or bonded to tank before testing and labeling.

Retain "Finish" Subparagraph below for steel tanks.

7. Finish: Hot-dip galvanized on exterior and interior of tank after fabrication.
8. Upper Distribution System: Single-point type, fabricated from galvanized-steel pipe and fittings.
9. Lower Distribution System: Hub and radial-arm or header-lateral type; fabricated from PVC pipe and fittings with individual, fine-slotted, nonclogging polyethylene strainers; arranged for even-flow distribution through resin bed.

F. Controls: Automatic; factory mounted on mineral tanks and factory wired.

1. Adjustable duration of regeneration steps.
2. Push-button start and complete manual operation override.
3. Pointer on pilot-control valve shall indicate cycle of operation.
4. Means of manual operation of pilot-control valve if power fails.
5. Main Operating Valves: Industrial, automatic, multiport, diaphragm type with the following features:

   a. Slow opening and closing, nonslam operation.
   b. Diaphragm guiding on full perimeter from fully open to fully closed.
   c. Isolated dissimilar metals within valve.
   d. Self-adjusting, internal, automatic brine injector that draws brine and rinses at constant rate independent of pressure.
   e. Float-operated brine valve to automatically measure the correct amount of brine to the softener, and refill with fresh water.

f. Sampling cocks for soft water.

6. Flow Control: Automatic control of backwash and flush rates over variations in operating pressures that do not require field adjustments. Equip mineral tanks with automatic-reset-head water meter that electrically activates cycle controller to initiate regeneration at preset total in gallons and that automatically resets after regeneration to preset total in gallons for next service run. Include alternator to regenerate one mineral tank with the other in service.

G. Brine Tank: Combination measuring and wet-salt storing system.

1. Tank and Cover Material: Fiberglass a minimum of 3/16 inch thick; or molded polyethylene a minimum of 3/8 inch thick.
2. Brine Valve: Float operated and plastic fitted for automatic control of brine withdrawn and freshwater refill.
3. Size: Large enough for at least four regenerations at full salting.

H. Factory-Installed Accessories:

1. Piping, valves, tubing, and drains.
2. Sampling cocks.
3. Main-operating-valve position indicators.
4. Water meters.

I. Water Test Kit: Include in wall-mounted enclosure for water softener.

If more than one water softener is required on Project, delete "Capacities and Characteristics" Paragraph below and schedule water softeners on Drawings.

J. Capacities and Characteristics:

1. Continuous Service Flow Rate: <**Insert gpm**> at 15-psig pressure loss.
2. Peak Service Flow Rate: <**Insert gpm**> at 25-psig pressure loss.
3. Water Consumption: <**Insert gal./day**>.
4. Water Demand: <**Insert number**> hours/day.
5. Electrical Characteristics:

a. Volts: <**Insert value**>.
b. Phase: <**Insert value**>.
c. Hertz: <**Insert value**>.
d. Full-Load Amperes: <**Insert value**>.
e. Minimum Circuit Ampacity: <**Insert value**>.
f. Maximum Overcurrent Protection: <**Insert amperage**>.
g. Interrupting Capacity: <**Insert amperage**>.

Consider retaining "RO Equipment for HVAC Makeup Water" Article below for use on high-pressure steam makeup or for other steam systems with greater than 8 percent makeup.

2.12 RO EQUIPMENT FOR HVAC MAKEUP WATER

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Description: Factory fabricated and tested with RO membrane elements in housings, high-pressure pumps and motors, controls, valves, and prefilter; mounted on skid.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain first paragraph below for projects in seismic areas; if retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

D. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure as recommended in writing by manufacturer.

E. Skid Assembly: Welded-steel frame coated with epoxy protective finish.

Modify details in "RO Membrane and Housing" Paragraph below where necessary to specify the products selected as basis of design.

F. RO Membrane and Housing:

1. Element: Thin-film composite with U-cup brine seal, with minimum 98 percent salt rejection based on 2000-ppm water supplied at 225 psig and 77 deg F.
2. Housing: ASTM A666, Type 304 stainless steel, with PVC end caps held in place with stainless steel straps.

Modify details in "High-Pressure Pumps and Motors" Paragraph below where necessary to specify the products selected as basis of design.

G. High-Pressure Pumps and Motors:

1. Pump:

a. Vertical, multistage, centrifugal pump, operating at 3500 rpm, with ASTM A666, Type 304 stainless steel casing, shaft, impellers, and inlet and discharge casting.
b. Bearings shall be tungsten carbide and ceramic.
c. Cast-iron frame and flanged suction and discharge connections.

Motor characteristics, such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency, are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

d. Motor: NEMA-standard, C-faced, totally enclosed, fan-cooled motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

H. Controls:

1. Microprocessor-based controller with digital display.
2. Interlock for remote start/stop control.

3. Membrane flush sequence when pumps shut down.
4. Run time indicator.
5. Low-pressure safety cutoff.
6. Panel-mounted gages as follows:

    a. Product and concentrate.
    b. Inlet, cartridge filter outlet, RO feed, RO concentrate, and RO product pressures.
    c. Product conductivity monitor.

I. Valves:

1. Stainless steel pump, concentrate, and recycle throttling valves rated for minimum 300 psig.
2. Automatic inlet shutoff valve, diaphragm type; solenoid actuated, normally closed, and constructed of glass-reinforced noryl thermoplastic.
3. PVC valves with EPDM seats and seals for isolation at inlet, and check and sample valves at product and concentrate. Install sample valves at cartridge filter outlet, concentrate, and product outlet.

J. Prefilter:

1. Housing: Polypropylene with built-in relief or vent valve.
2. Element: Spun-wound polypropylene.

K. Inlet Water-Tempering Valve: Thermostatic water-tempering valve to maintain [**77 deg F**] <**Insert value**> inlet water temperature to RO unit.

L. Activated Carbon Filter:

1. Media Tank: Fiberglass-reinforced polyester rated for minimum 150 psig with internal backwash distributor and filtered water collector.
2. Media: 12-by-40-mesh, bituminous coal-based activated carbon.
3. Backwash Valve: Piston-operated control valve with drain-line, flow-control orifice.
4. Backwash Control: Seven-day time clock.

M. Atmospheric Storage Tank:

1. Tank: Polyethylene single piece with closed top and flat bottom with manway in top, 0.2-micron filter vent, inlet, discharge, and drain piping connections, and bulkhead fittings for level controls.
2. Control: Level switches start and stop RO unit. Low-level limit shall stop repressurization pumps and signal an alarm.

N. Repressurization Pumps:

1. Pumps: Two close-coupled, single-stage centrifugal pumps with mechanical seals. Wetted components are made of ASTM A666, Type 316 stainless steel.
2. Controls: NEMA 250, Type 4X pump control panel constructed of fiberglass to control pumps, one operating and one standby, with automatic alternator and fail-over control.

Motor characteristics, such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency, are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

3. Motor: Open, drip-proof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

    a. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

O. Water Test Kit: Include in wall-mounting cabinet for RO unit.

If more than one RO unit is required on Project, delete "Capacities and Characteristics" Paragraph below and schedule RO units on Drawings.

P. Capacities and Characteristics:

1. RO Product Flow Rate: <**Insert gpm**>.
2. Total Water-Flow Rate: <**Insert gpm**>.
3. Daily Water Consumption: <**Insert gal./day**>.
4. Water Demand: <**Insert number**> hours/day.
5. Storage Tank Size: <**Insert gal.** >.
6. RO Inlet Operating Temperature: [**77 deg F**] <**Insert value**>.
7. High-Pressure Pump:

    a. Discharge Pressure: <**Insert psig**>.
    b. Flow Rate: <**Insert gpm**>.
    c. Horsepower: <**Insert value**>.
    d. Motor Speed: [**3500**] <**Insert number**> rpm.

8. Repressure Pumps:

    a. Discharge Pressure: <**Insert psig**>.
    b. Flow Rate: <**Insert gpm**>.
    c. Horsepower: <**Insert value**>.
    d. Motor Speed: [**3500**] <**Insert number**> rpm.

9. Prefilter Design (at Total Water-Flow Rate):

    a. Filter Efficiency: [**98**] <**Insert number**> percent.
    b. Particle Size: [**5**] <**Insert number**> microns and larger.
    c. Clean Pressure Loss: [**2 psig**] <**Insert value**>.
    d. Replacement Pressure Loss: [**6 psig**] <**Insert value**>.

10. Electrical Characteristics (Single-Point Connection):

    a. Volts: <**Insert value**>.
    b. Phase: <**Insert value**>.
    c. Hertz: <**Insert value**>.
    d. Full-Load Amperes: <**Insert value**>.

e. Minimum Circuit Ampacity: <**Insert value**>.
f. Maximum Overcurrent Protection: <**Insert amperage**>.
g. Interrupting Capacity: <**Insert amperage**>.

2.13 FILTRATION EQUIPMENT

A. Multimedia Filters:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description: Factory-fabricated and -tested, simplex, multimedia filter system, consisting of filter tank, media, strainer, circulating pump, piping, and controls for removing particles from water.

    a. Filter Tank: Corrosion resistant with distribution system and media.

3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Retain first subparagraph below to require steel or stainless steel tanks to be ASME labeled; delete for non-code construction.

a. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

Retain first subparagraph below to require FRP tanks to be ASME labeled; delete for non-code construction.

b. Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
c. Pipe Connections NPS 2 and Smaller: Threaded in accordance with ASME B1.20.1.
d. Steel Tank Pipe Connections NPS 2-1/2 and Larger: Steel, Class 150 flanges in accordance with ASME B16.5 or grooved in accordance with AWWA C606.
e. FRP Tank Pipe Connections NPS 2-1/2 and Larger: Type A, integral; [**Designation E, 125-psig**] [**or**] [**Designation F, 150-psig**] pressure category flanges of grade same as tank material, in accordance with ASTM D5421.
f. Motorized Valves: Flanged or grooved-end, ductile-iron butterfly type with [**EPDM**] <**Insert material**> valve seat and stem seal; with ASTM B148 aluminum bronze disc.
g. Strainer: Basket type mounted on pump suction.

Retain one of two "Piping" subparagraphs below.

h. Piping: ASTM A53/A53M; Type S, F, or E; Grade B; Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding or ductile-iron fittings.
i. Piping: ASTM B88, Type L copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
j. Safety Valves: Automatic pressure relief.
k. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.

1) Casing: Radially split, cast iron.
2) Pressure Rating: [**125 psig**] [**150 psig**] minimum.
3) Impeller: ASTM B584 cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
4) Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
5) Seal: Mechanical.

Motor characteristics, such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency, are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

6) Motor: Open, dripproof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

l. Controls: Automatic control of circulating pump and tank backwash; factory wired for single electrical connection.

1) Panel: NEMA 250, [**Type 4**] <**Insert type**> enclosure with time clock and pressure gages.
2) Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
3) Backwash: Automatic; with time clock and differential pressure switch.
4) Backwash Valve: Tank mounted with valves interlocked to single actuator.

Retain option in "Support" Subparagraph below for projects in seismic areas; if retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

m. Support: Skid mounting.[**Fabricate supports, base, and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event, when filter base is anchored to building structure.**]

If more than one circulating multimedia filter is required on Project, delete "Capacities and Characteristics" Subparagraph below and schedule multimedia filters on Drawings.

4. Capacities and Characteristics:

a. Filter Design:

1) Water Flow: <**Insert gpm**>.
2) Clean Pressure Loss: [**5 psig**] <**Insert value**>.
3) Maximum Media-Flow Rate: [**15 gpm/sq. ft.**] <**Insert value**>.
4) Filtration Efficiency: [**98**] <**Insert number**> percent.
5) Particle-Specific Gravity: [**1.8**] <**Insert number**>.
6) Particle Size: [**5**] [**10**] [**20**] [**45**] <**Insert number**> microns.

b. Filter Tank: With internal distribution piping.

1) Pressure Rating: <**Insert psig**>.
2) Diameter: <**Insert inches**>.
3) Inlet and Outlet Size: <**Insert NPS**>.
4) Blowdown Piping Outlet Size: <**Insert NPS**>.

c. Filter Media: <**Insert material**>.
d. Start Backwash Pressure Loss: [**13 psig**] <**Insert value**>.
e. Backwash Period: [**10**] <**Insert number**> minutes.
f. Circulating Pump:

1) Capacity: <**Insert gpm**>.
2) Total Dynamic Head: <**Insert feet**>.
3) Motor Speed: <**Insert number**> rpm.
4) Inlet Size: <**Insert NPS**>.
5) Outlet Size: <**Insert NPS**>.

g. Pump Motor Size and Electrical Characteristics:

1) Horsepower: <**Insert value**>.
2) Volts: [**120**] [**208**] [**240**] [**277**] [**480**] <**Insert number**> V.
3) Phase: [**Single**] [**Three**].
4) Hertz: [**60**] <**Insert number**> Hz.

h. Unit Electrical Characteristics:

1) Full-Load Amperes: <**Insert value**>.
2) Minimum Circuit Ampacity: <**Insert value**>.
3) Maximum Overcurrent Protection: <**Insert amperage**>.
4) Interrupting Capacity: <**Insert amperage**>.

B. Self-Cleaning Strainers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description: Factory-fabricated and -tested, ASTM A126, Class B, cast-iron or steel, self-cleaning strainer system of tank, strainer, backwash arm or cleaning spiral, drive and motor, piping, and controls for removing particles from water.

a. Fabricate and label ASTM A126, Class B, cast-iron or steel strainer tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
b. Pipe Connections:

1) NPS 2 and Smaller: Threaded in accordance with ASME B1.20.1.
2) NPS 2-1/2 and Larger: Steel, Class 150 flanges in accordance with ASME B16.5 or grooved in accordance with AWWA C606.

3. Motorized Valves: Flanged or grooved-end, ductile-iron angle type with [**EPDM**] <**Insert material**> valve seat and stem seal; with ASTM B148 aluminum bronze disc.
4. Strainer: ASTM A666, Type 316 stainless steel.
5. Piping: ASTM A53/A53M; Type S, F, or E; Grade B; Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding or ductile-iron fittings.
6. Safety Valves: Automatic pressure relief.

Hydraulic drive on some units makes motorized drive unnecessary.

7. Backwash Arm Drive:

a. Drive Casing: Cast iron.

b. Worm Gears: Immersed in oil.

Motor characteristics, such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency, are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

c. Motor: Open, dripproof motor supported on the strainer-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

8. Controls: Automatic control of backwash; factory wired for single electrical connection.

a. Panel: NEMA 250, [**Type 4**] <**Insert type**> enclosure with time clock and pressure gages.
b. Backwash Arm Drive: Automatic and manual switching; manual switch position bypasses safeties and controls.
c. Backwash: Automatic; with time clock and differential pressure switch.
d. Backwash Valve: Electric actuator.

Retain option in "Support" Subparagraph below for projects in seismic areas; if retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

9. Support: Skid mounting.[**Fabricate supports, base, and attachment to tank with reinforcement strong enough to resist strainer movement during a seismic event, when strainer base is anchored to building structure.**]

If more than one strainer is required on Project, delete "Capacities and Characteristics" Subparagraph below and schedule strainers on Drawings.

10. Capacities and Characteristics:

a. Strainer Design:

1) Water Flow: <**Insert gpm**>.
2) Clean Pressure Loss: [**5 psig**] <**Insert value**>.
3) Strainer Mesh: [**40**] [**60**] [**80**] <**Insert number**>.

b. Strainer Tank: With internal distribution piping.

1) Material: [**Cast iron**] [**Steel**] <**Insert material**>.
2) Pressure Rating: [**150 psig**] <**Insert value**>.
3) Inlet and Outlet Size: <**Insert NPS**>.
4) Backwash Piping Outlet Size: <**Insert NPS**>.

c. Start Backwash: [**10 psig**] <**Insert value**>.
d. Backwash Period: [**5**] <**Insert number**> minutes.

Hydraulic drive on some units makes motorized drive unnecessary.

e. Drive Motor Size and Electrical Characteristics:

1) Horsepower: <**Insert value**>.
2) Volts: [**120**] [**208**] [**240**] [**277**] [**480**] <**Insert number**> V.
3) Phase: [**Single**] [**Three**].

4) Hertz: [**60**] <**Insert number**> Hz.

f. Unit Electrical Characteristics:

1) Full-Load Amperes: <**Insert value**>.
2) Minimum Circuit Ampacity: <**Insert value**>.
3) Maximum Overcurrent Protection: <**Insert amperage**>.
4) Interrupting Capacity: <**Insert amperage**>.

C. [**Bag**] [**Cartridge**]-Type Filters:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description: [**Floor-mounted housing**] [**Housing**] with filter [**bags**] [**cartridges**] for removing particles from water.

a. Housing: Corrosion resistant; designed to separate inlet from outlet and to direct inlet through [**bag**] [**cartridge**]-type water filter; with [**bag support and**]base, feet, or skirt.

1) Pipe Connections NPS 2 and Smaller: Threaded in accordance with ASME B1.20.1.
2) Steel Housing Pipe Connections NPS 2-1/2 and Larger: Steel, Class 150 flanges in accordance with ASME B16.5 or grooved in accordance with AWWA C606.
3) Plastic Housing Pipe Connections NPS 2-1/2 and Larger: 150-psig plastic flanges.

b. [**Bag**] [**Cartridge**]: Replaceable; of shape to fit housing.

If more than one bag- or cartridge-type filter is required on Project, delete "Capacities and Characteristics" Subparagraph below and schedule bag- or cartridge-type filters on Drawings.

3. Capacities and Characteristics:

a. Filter Design:

1) Water-Flow Rate: <**Insert gpm**>.
2) Filtration Efficiency: [**98**] <**Insert number**> percent.
3) Particle Size: [**10**] [**20**] <**Insert number**> microns and larger.
4) Clean Pressure Loss: [**2 psig**] <**Insert value**>.
5) Pressure Loss at Replacement: [**6 psig**] <**Insert value**>.

b. Housing:

1) Material: [**Carbon steel**] [**Plastic**].
2) Pressure Rating: <**Insert psig**>.
3) Seal Material: [**Nitrile rubber**] <**Insert material**>.
4) Diameter: <**Insert inches**>.
5) Height or Length: <**Insert inches**>.
6) Inlet and Outlet Size: <**Insert NPS**>.
7) Drain Size: [**Not applicable**] <**Insert NPS**>.

8) Bag Support Basket Material: [**Stainless steel**] <**Insert material**>.

c. [**Bag**] [**Cartridge**]:

1) Number Required: <**Insert number**>.
2) Nominal Diameter: <**Insert inches**>.
3) Nominal Length: <**Insert inches**>.
4) Media Material: [**Cotton**] [**Polyester**] [**Polypropylene**] <**Insert material**>.

D. Centrifugal Separators:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Description: Simplex separator housing, with baffles and chambers for removing particles from water by centrifugal action and gravity.
3. Housing: With manufacturer's proprietary system of baffles and chambers.

a. Construction: Fabricate and label steel separator housing to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
b. Inlet: Designed with tangential entry to produce centrifugal flow of feedwater.
c. Vortex Chamber: Designed for downward vortex flow and gravity separation of particles.
d. Collection Chamber: Designed to hold separated particles.
e. Outlet: Near top of unit.
f. Purge: At bottom of collection chamber.
g. Pipe Connections NPS 2 and Smaller: Threaded in accordance with ASME B1.20.1.
h. Pipe Connections NPS 2-1/2 and Larger: Steel, Class 150 flanges in accordance with ASME B16.5 or grooved in accordance with AWWA C606. Provide stainless steel flanges if tank is stainless steel.

4. Motorized Purge Valve: Gate or plug pattern valve.

a. Motorized Valves: Butterfly-type, flanged or grooved-end, ductile-iron body, with [**EPDM**] <**Insert material**> valve seat and stem seal; with ASTM B148 aluminum bronze disc.
b. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

5. Strainer: Stainless steel basket type mounted on pump suction.

Retain "Piping, Steel" or "Piping, Copper" Subparagraph below.

6. Piping, Steel: ASTM A53/A53M; Type S, F, or E; Grade B; Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding or ductile-iron fittings.
7. Piping, Copper: ASTM B88, Type L copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
8. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.

a. Casing: Radially split, cast iron.

b. Pressure Rating: [**125 psig**] [**150 psig**] minimum.
c. Impeller: ASTM B584 cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
d. Shaft and Shaft Sleeve: Steel shaft with copper-alloy shaft sleeve.
e. Seal: Mechanical.

Motor characteristics, such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency, are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, add subparagraphs below to suit Project.

f. Motor: Open, dripproof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
g. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

9. Controls: Automatic control of circulating pump and separator purge; factory wired for single electrical connection.

a. Panel: NEMA 250, [**Type 4**] <**Insert type**> enclosure.
b. Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
c. Separator Purge: Automatic and manual.
d. TSS Controller Interlock: Open separator purge valve with bleed-off control.

Retain option in "Support" Subparagraph below for projects in seismic areas; if retaining, also retain "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article.

10. Support: Skid mounting.[**Fabricate supports, base, and attachment to separator housing with reinforcement strong enough to resist separator movement during a seismic event, when separator base is anchored to building structure.**]

If more than one separator is required on Project, delete "Capacities and Characteristics" Subparagraph below and schedule separators on Drawings.

11. Capacities and Characteristics:

a. Separator Design:

1) Water-Flow Rate: <**Insert gpm**>.
2) Pressure Loss: [**5 psig**] <**Insert value**>.
3) Separator Efficiency: [**98**] <**Insert number**> percent.
4) Particle-Specific Gravity: [**1.8**] <**Insert number**>.
5) Particle Size: [**5**] [**10**] [**20**] [**45**] <**Insert number**> microns.

b. Housing:

1) Material: [**Steel**] [**Stainless steel**] [**Plastic**] [**Fiberglass**] <**Insert material**>.
2) Pressure Rating: <**Insert psig**>.
3) Diameter: <**Insert inches**>.
4) Height: <**Insert inches**>.
5) Inlet and Outlet Size: <**Insert NPS**>.

6) Purge Size: <**Insert NPS**>.

Retain "Circulating Pump" Subparagraph below only if separator is circulating type.

c. Circulating Pump:

1) Capacity: <**Insert gpm**>.
2) Total Dynamic Head: <**Insert feet**>.
3) Motor Speed: <**Insert number**> rpm.
4) Inlet Size: <**Insert NPS**>.
5) Outlet Size: <**Insert NPS**>.

d. Pump Motor Size and Electrical Characteristics:

1) Horsepower: <**Insert value**>.
2) Volts: [**120**] [**208**] [**240**] [**277**] [**480**] <**Insert number**> V.
3) Phase: [**Single**] [**Three**].
4) Hertz: [**60**] <**Insert number**> Hz.
5) Full-Load Amperes: <**Insert value**>.
6) Minimum Circuit Ampacity: <**Insert value**>.
7) Maximum Overcurrent Protection: <**Insert amperage**>.
8) Interrupting Capacity: <**Insert amperage**>.

PART 3 - EXECUTION

3.1 WATER ANALYSIS

Delete this article if water analysis has been or will be performed by Owner.

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION

Coordinate this article with Drawings.

A. Install chemical-application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate. Install all chemical application equipment within a spill-containment area without floor drains.

Retain first paragraph below for Project in a seismic area. Add special requirements for seismic restraints here, or indicate on Drawings.

B. Install seismic restraints for equipment and floor-mounting accessories, and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

C. Install water-testing equipment on wall near water-chemical-application equipment.

D. Install interconnecting control wiring for chemical-treatment controls and sensors.

E. Mount sensors and injectors in piping circuits.

F. Bypass Feeders: Install in closed hydronic systems, including[**hot-water heating,**][**chilled water,**][**dual-temperature water,**][**glycol heating,**][**and**][**glycol cooling**], and equip with the following:

1. Install bypass feeder in a bypass circuit around circulating pumps unless otherwise indicated on Drawings.

Retain first subparagraph below for closed systems larger than 400 gpm (24 L/s).

2. Install water meter in makeup-water supply.
3. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
4. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.
5. Install a swing check on inlet after the isolation valve.

G. Install automatic fluid make-up equipment for glycol water system and include the following:

1. Chemical solution tanks.
2. Chemical solution injection pumps.
3. Water meter in makeup supply to system.
4. Pressure switch to operate injection pump as necessary to maintain glycol system pressure.

H. Install automatic chemical-feed equipment for steam boiler and steam condensate systems and include the following:

1. Install makeup-water softener.
2. Install water meter in makeup-water supply.
3. Install inhibitor injection pumps and solution tanks with injection-timer-sensing contacts in water meter.

   a. Pumps shall operate for timed interval when contacts close at water meter in makeup-water supply connection.

4. Install test equipment and furnish test-kit to Owner.

Do not retain first subparagraph below if RO unit is not specified in Part 2.

5. Install RO unit for makeup water.
6. Install TDS controller with sensor and bleed valves.

   a. Bleed valves to cycle, to maintain maximum TDS concentration.

7. Install TSS controller with sensor and bleed valves.

   a. Bleed valves to cycle, to maintain maximum TSS concentration.

Retain subparagraph below for steam-condensate treatment with amines.

8. Install inhibitor injection timer with injection pumps and solution tanks.

    a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into main steam supply header.

I. Install automatic chemical-feed equipment for open [**condenser**] [**fluid-cooler spray**] water and include the following:

1. Install water meter in makeup-water supply.
2. Install inhibitor injection pumps and solution tanks with injection-timer-sensing contacts in water meter.

    a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.

3. Install test equipment, and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
4. Install TDS controller with sensor and bleed valves.

    a. Bleed valves to cycle, to maintain maximum TDS concentration.

5. Install TSS controller with sensor and bleed valves.

    a. Bleed valves to cycle, to maintain maximum TSS concentration.

6. Install pH sensor and controller with injection pumps and solution tanks.

    a. Injector pumps shall operate to maintain required pH.

Retain one of three subparagraphs below.

7. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.

    a. Injection pumps shall operate to feed biocide on an alternating basis.

8. Install ozone generator with diffusers in condenser-water piping.

    a. Ozone generator shall operate continuously with condenser-water flow.

9. Install UV-irradiation lamps in condenser-water piping.

    a. UV lights shall operate continuously with condenser-water flow.

3.3 OZONE-GENERATOR INSTALLATION

A. Install ozone generator and equipment on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.

Retain first paragraph below for Project in a seismic area. Add special requirements for seismic restraints here, or indicate on Drawings.

B. Install seismic restraints for equipment and floor-mounting accessories, and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

C. Pipe ozone from ozone generator to condenser water with stainless steel pipe and fittings with welded joints.

D. Install [**two**] [**three**]-piece, stainless steel ball valve in ozone supply to condenser water.

E. Pipe cooling water to ozone generator and to air-gap drain fitting with stainless steel pipe and fittings with welded joints where enclosed in ozone-generator room.

F. Install [**two**] [**three**]-piece, stainless steel ball valve in cooling water supply to ozone generator.

G. Mounting supports for ozone generator shall be ASTM A666, Type 316 stainless steel.

H. Mount breathing apparatus outside ozone-generator room.

I. Mount and install ozone detector, warning lights, and audible alarm inside ozone-generator room. Mount another set of warning lights and audible alarm just outside the main entrance to ozone-generator room.

3.4 UV-IRRADIATION UNIT INSTALLATION

A. Install UV-irradiation units on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.

Retain paragraph below for Project in a seismic area. Add special requirements for seismic restraints here, or indicate on Drawings.

B. Install seismic restraints for UV-irradiation units and floor-mounting accessories, and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

3.5 WATER SOFTENER INSTALLATION

A. Install water softener equipment on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.

Retain first paragraph below for Project in a seismic area. Add special requirements for seismic restraints here, or indicate on Drawings.

B. Install seismic restraints for tanks and floor-mounting accessories, and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

C. Install brine lines and fittings furnished by equipment manufacturer but not factory installed.

D. Prepare mineral-tank distribution system and underbed for minerals, and place specified mineral into mineral tanks.

E. Install water-testing sets on wall adjacent to water softeners.

3.6 RO UNIT INSTALLATION

A. Install RO unit and storage tank on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor RO unit and storage tank with pumps to substrate.

Retain first paragraph below for Project in a seismic area. Add special requirements for seismic restraints here, or indicate on Drawings.

B. Install seismic restraints for tanks and floor-mounting accessories, and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

C. Install interconnecting piping and controls furnished by equipment manufacturer but not factory installed.

D. Install water-testing sets on wall adjacent to RO unit.

3.7 PIPING CONNECTIONS

Coordinate piping installations and specialty arrangements with Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to equipment, allow space for service and maintenance.

C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Section 232113 "Hydronic Piping."

D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."

E. See Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.

3.8 ELECTRICAL CONNECTIONS

A. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.

B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

C. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.9 FIELD QUALITY CONTROL

Retain one of first four paragraphs below. Retain first "Testing Agency" Paragraph below if Owner will hire an independent testing agency.

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

Retain "Testing Agency" Paragraph below to require Contractor to hire an independent testing agency.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform tests and inspections" Paragraph below to require Contractor to perform tests and inspection, and retain option to require Contractor to arrange for the assistance of a factory-authorized service agent.

D. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].

Retain test requirements below with any combination of paragraphs above.

E. Tests and Inspections:

1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
3. Place HVAC water-treatment system into operation, and calibrate controls during the preliminary phase of HVAC system's startup procedures.

4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
7. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
8. Repair leaks and defects with new materials, and retest piping until no leaks exist.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

F. Equipment will be considered defective if it does not pass tests and inspections.

G. Prepare test and inspection reports.

Add to or delete tests to suit Project. For definitions of terms used in sampling and testing, see ASTM D1129.

H. Sample boiler water at one-week intervals after boiler startup for a period of five weeks, and prepare test report, advising Owner of changes necessary to adhere to "Performance Requirements" Article for each required characteristic. Sample boiler water at [**four**] [**six**] [**eight**] <**Insert number**>-week intervals following the testing noted above to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section.

I. At [**four**] [**six**] [**eight**] <**Insert number**>-week intervals following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis, advising Owner of changes necessary to adhere to "Performance Requirements" Article.

J. Comply with ASTM D3370 and with the following standards:

1. Silica: ASTM D859.
2. Steam System: ASTM D1066.
3. Acidity and Alkalinity: ASTM D1067.
4. Iron: ASTM D1068.
5. Water Hardness: ASTM D1126.

3.10 MAINTENANCE SERVICE

Verify with Owner that maintenance service is required for Project.

A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above, to inhibit corrosion, scale formation, and biological growth for [**cooling, chilled-water piping**] [**heating, hot-water piping**] [**heating, steam and condensate piping**] [**steam and condensate system for humidifier and cooking appliance applications**] [**condenser-water piping**] and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion and shall include the following:

1. Initial water analysis and HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
3. Periodic field service and consultation.
4. Customer report charts and log sheets.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

3.11 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

B. Training: Provide a "how-to-use" self-contained breathing apparatus video that details exact operating procedures of equipment. When training is complete, turn over video to Owner for future use.

END OF SECTION 232500

SECTION 232513 - WATER TREATMENT FOR CLOSED-LOOP HYDRONIC SYSTEMS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

Use Section 232500 "HVAC Water Treatment" for Project that includes HVAC water treatment for both open- and closed-loop systems. Use this Section if Project includes HVAC chemical treatment for only closed-loop systems.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes the following water treatment for closed-loop hydronic systems:

1. [**Manual**] [**Automatic**] chemical-feed equipment.
2. Chemicals.

B. Related Requirements:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 232533 "HVAC Makeup-Water Filtration Equipment" for water treatment of water softeners, RO equipment, and filtration equipment.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. RO: Reverse osmosis.

B. TDS: Total dissolved solids consist of salts and other materials that combine with water as a solution.

C. TSS: Total suspended solids include both organic and inorganic solids that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, and furnished specialties and accessories for the following products:

1. Bypass feeders.
2. Water meters.
3. Inhibitor injection timers.
4. pH controllers.
5. Chemical solution tanks.
6. Injection pumps.
7. Chemical-treatment test equipment.
8. Chemical material safety data sheets.
9. Inhibited ethylene glycol.
10. Inhibited propylene glycol.

B. Shop Drawings: Pretreatment and chemical-treatment equipment, showing tanks, maintenance space required, and piping connections to hydronic systems.

1. Include plans, elevations, sections, and attachment details.
2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

A. Seismic Qualification Certificates: For components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

See Section 014000 "Quality Requirements" for a definition of the term "experience."

B. Water-Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

Retain "Water-Treatment Program" Paragraph below if retaining "Maintenance Service" Article.

D. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.

E. Water Analysis: Illustrate water quality available at Project site.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

See Section 014000 "Quality Requirements" for a definition of the term "experienced."

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider, capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 HVAC WATER-TREATMENT MANUFACTURERS

Retain this article to require a single-source responsibility for all water-treatment equipment and materials.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.2 PERFORMANCE REQUIREMENTS

The companies listed above supply water-treatment chemicals and equipment. They will also furnish and install all required hardware and provide a complete on-site HVAC water-treatment program.

A. Provide all hardware, chemicals, and other material necessary to maintain HVAC water quality in all systems, as indicated in this Specification. Water quality for hydronic systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of hydronic equipment without creating a hazard to operating personnel or the environment.

B. Base HVAC water treatment on quality of water available at Project site, hydronic system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

Desirable water-quality values differ widely, depending upon raw water conditions, piping system materials, and service conditions. Recommendations from water-treatment companies vary. Specified target values must be determined by careful consideration of all operating conditions and with the assistance of a qualified water chemistry expert.

C. Closed hydronic systems, including [**hot-water heating below 250 deg F**] [**chilled water**] [**dual-temperature water**] [**glycol heating**] [**and**] [**glycol cooling**] shall have the following water qualities:

1. pH: Maintain a value within <**Insert range**>.
2. Alkalinity: Maintain a value within <**Insert range**> mg/L as CaCO(3).
3. Steel Corrosion Inhibiters: Provide sufficient inhibitors to limit mild steel corrosion to <**Insert number**> mils per year. Maintain soluble iron concentrations at or below <**Insert value**> mg/L.
4. Yellow Metal Corrosion Inhibitor: Provide sufficient copper and brass corrosion inhibitors to limit copper corrosion to <**Insert number**> mils per year. Maintain soluble copper concentrations at or below <**Insert value**> mg/L.
5. Scale Control: Provide softened water for initial fill and makeup. [**Where softened water is not used, provide sufficient scale inhibitors to prevent formation of scale and maintain all scale-forming material in solution.**]
6. Dispersants: Provide sufficient dispersants to prevent sedimentation of fine particulate matter.
7. Microbiological Limits:

   a. Total Aerobic Plate Count: Maintain a maximum value of <**Insert number**> organisms/mL.
   b. Total Anaerobic Plate Count: Maintain a maximum value of <**Insert number**> organisms/mL.
   c. Nitrate Reducers: Maintain a maximum value of <**Insert number**> organisms/mL.
   d. Sulfate Reducers: Maintain a maximum value of <**Insert number**> organisms/mL.
   e. Iron Bacteria: Maintain a maximum value of <**Insert number**> organisms/mL.

8. <**Insert other applicable requirements**>.

2.3 MANUAL CHEMICAL-FEED EQUIPMENT

Retain this article for closed piping systems, such as chilled-water, hot-water, and dual-temperature piping.

A. Bypass Feeders: Provide steel feeders with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Provide quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.

1. Capacity: [**2 gal.**] [**5 gal.**] <**Insert value**>.
2. Minimum Working Pressure: [**125 psig**] [**175 psig**] <**Insert value**>.

2.4 AUTOMATIC CHEMICAL-FEED EQUIPMENT

Retain one or more of "Water Meter, Piston Type, Threaded," "Water Meter, Turbine Type, Threaded," and "Water Meter, Turbine Type, Flanged" paragraphs below. If retaining more than one paragraph, indicate on Drawings where meters are to be installed. Large closed systems, of more than 400 gpm (25 L/s), should be equipped with a meter. Coordinate type of meter signal with requirements of controller and DDC system.

A. Water Meter, Piston Type, Threaded:

1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 150 psig.
4. Maximum Pressure Loss at Design Flow: 3 psig.
5. Registration: Gallons or cubic feet.
6. End Connections: Threaded.
7. [**Controls: Flow-control switch with normally open contacts, rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.**]
8. [**Electronic or digital interface for flow rate indication at central workstation compatible with DDC system, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC." Low-voltage signal must be capable of transmitting 1000 feet.**]
9. [**Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.**]

B. Water Meter, Turbine Type, Threaded:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 100 psig.
4. Maximum Pressure Loss at Design Flow: 3 psig.
5. Registration: Gallons or cubic feet.
6. End Connections: Threaded.
7. [**Controls: Flow-control switch with normally open contacts. rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.**]

8. [**Electronic or digital interface for flow rate indication at central workstation compatible with DDC system, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC." Low-voltage signal must be capable of transmitting 1000 feet.**]
9. [**Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.**]

C. Water Meter, Turbine Type, Flanged:

1. AWWA C701, turbine-type, totalization meter.
2. Body: [**Bronze**] [**Epoxy-coated cast iron**].
3. Minimum Working-Pressure Rating: 150 psig.
4. Maximum Pressure Loss at Design Flow: 3 psig.
5. Registration: Gallons or cubic feet.
6. End Connections: Flanged.
7. [**Controls: Flow-control switch with normally open contacts, rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.**]
8. [**Electronic or digital interface for flow rate indication at central workstation compatible with DDC system, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC." Low-voltage signal must be capable of transmitting 1000 feet.**]
9. [**Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.**]

D. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: [**30 gal.**] [**50 gal.**] [**120 gal.**] <**Insert value**>.

E. Chemical Solution Injection Pumps:

1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.

Motor characteristics, such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency, are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert subparagraphs below to suit Project.

5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

F. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A269/A269M, Type 304 stainless steel for steam boiler injection assemblies.

G. Injection Assembly:

1. Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: [**Three**] [**Two**]-piece, stainless steel; selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 600 psig at 200 deg F.

2.5 CHEMICAL-TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounted cabinet for testing pH, corrosion inhibitors, alkalinity, hardness, and other properties recommended by manufacturer.

B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

1. [**Two**] <**Insert number**>-station rack for closed-loop systems.

2.6 CHEMICALS

Revise this article to suit local conditions and recommendations of chemical-treatment manufacturer.

A. Chemicals shall be as recommended by water-treatment system manufacturer, compatible with piping system components and connected equipment, and able to attain water quality specified in "Performance Requirements" Article.

Before retaining "Inhibited Ethylene Glycol" Paragraph below, due to toxicity concerns, verify if ethylene glycol is permitted for use in specific application by locally enforced codes and authorities having jurisdiction.

2.7 INHIBITED ETHYLENE GLYCOL AND PROPYLENE GLYCOL

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Inhibited Ethylene Glycol:

1. Ethylene glycol with inhibitor additive, to provide freeze protection for heat-transfer fluid and corrosion protection for carbon-steel, brass, copper, stainless steel, and cast-iron piping and fittings.
2. Inhibitor creates a passive layer on all surfaces that contact ethylene glycol to prevent corrosion and stabilizes fluid pH, to compensate for acids formed from glycol degradation.

3. pH value shall be maintained between [**9.0 and 10.5**]<**Insert range**>, with reserve alkalinity greater than [**12**]<**Insert number**> mL.
4. Concentrated inhibited ethylene glycol is to be 95.5 percent ethylene glycol by weight and 4.5 percent performance additives.
5. Concentrated inhibited ethylene glycol is mixed with water in proper proportion specified by the manufacturer to provide freeze protection to [**minus 20 deg F**] <**Insert number**>. Premixed heat-transfer fluid may be used, or glycol/water mixture may be prepared at time of installation. Use only deionized water for mixing.
6. Provide only ethylene glycol that is specifically blended for HVAC application. Automotive-type antifreeze is unacceptable.

C. Inhibited Propylene Glycol:

1. Propylene glycol with inhibitor additive, to provide freeze protection for heat-transfer fluid and corrosion protection for carbon steel, brass, copper, stainless steel, and cast-iron piping and fittings.
2. Inhibitor creates a passive layer on all surfaces that contact propylene glycol to prevent corrosion and stabilizes fluid pH, to compensate for acids formed from glycol degradation.
3. pH value shall be maintained between <**Insert range**>, with reserve alkalinity greater than <**Insert number**> mL.
4. Concentrated inhibited propylene glycol is to be 95.5 percent propylene glycol by weight and 4.5 percent performance additives.
5. Concentrated inhibited propylene glycol is mixed with water in proper proportion specified by the manufacturer to provide freeze protection to [**minus 20 deg F**] <**Insert number**>. Premixed heat-transfer fluid may be used, or glycol/water mixture may be prepared at the time of installation. Use only deionized water for mixing.
6. Provide only propylene glycol that is specifically blended for HVAC application. Automotive-type antifreeze is unacceptable.

PART 3 - EXECUTION

3.1 WATER ANALYSIS

Delete this article if water analysis has been or will be performed by Owner.

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION

Coordinate this article with Drawings.

A. Install chemical-application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate. Install all chemical application equipment within a spill-containment area without floor drain.

Retain first paragraph below for Project in a seismic area. Add special requirements for seismic restraints here or indicate on Drawings.

B. Install seismic restraints for equipment and floor-mounting accessories, and anchor to building structure. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.

C. Install water-testing equipment on wall near water-chemical-application equipment.

D. Install interconnecting control wiring for chemical-treatment controls and sensors.

E. Mount sensors and injectors in piping circuits.

F. Bypass Feeders: Install in closed hydronic systems, including[**hot-water heating,**][**chilled water,**][**dual-temperature water,**][**glycol heating,**][**and**][**glycol cooling**], and equip with the following:

1. Install bypass feeder in a bypass circuit around circulating pumps unless indicated otherwise on Drawings.

Retain first subparagraph below for closed systems larger than 400 gpm (24 L/s).

2. Install water meter in makeup-water supply.
3. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
4. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below the feeder inlet.
5. Install a swing check on the inlet after the isolation valve.

G. Install automatic fluid make-up equipment for glycol water system, and include the following:

1. Chemical solution tanks.
2. Chemical solution injection pumps.
3. Water meter in makeup supply to system.
4. Pressure switch to operate injection pump as necessary to maintain glycol system pressure.

3.3 PIPING CONNECTIONS

Coordinate piping installations and specialty arrangements with Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

A. Piping installation requirement are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to equipment, allow space for service and maintenance.

C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Section 232113 "Hydronic Piping."

D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."

E. Comply with requirements in Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.

3.4 ELECTRICAL CONNECTIONS

A. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.

B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

C. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.5 FIELD QUALITY CONTROL

Retain one of first four paragraphs below. Retain first "Testing Agency" Paragraph below if Owner will hire an independent testing agency.

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

Retain "Testing Agency" Paragraph below to require Contractor to hire an independent testing agency.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform tests and inspections" Paragraph below to require Contractor to perform tests and inspection, and retain option to require Contractor to arrange for the assistance of a factory-authorized service agent.

D. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].

Retain test requirements below with any combination of paragraphs above.

E. Tests and Inspections:

1. Inspect field-assembled components and equipment installation, including piping and electrical connections.

2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of hydronic systems' startup procedures.
4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
7. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
8. Repair leaks and defects with new materials, and retest piping until no leaks exist.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

F. Equipment will be considered defective if it does not pass tests and inspections.

G. Prepare test and inspection reports.

Add to or delete tests to suit Project. For definitions of terms used in sampling and testing, see ASTM D1129.

H. At [**four**] [**six**] [**eight**] <**Insert number**>-week intervals following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis, advising Owner of changes necessary to adhere to "Performance Requirements" Article.

I. Comply with ASTM D3370 and with the following standards:

1. Silica: ASTM D859.
2. Acidity and Alkalinity: ASTM D1067.
3. Iron: ASTM D1068.
4. Water Hardness: ASTM D1126.

3.6 MAINTENANCE SERVICE

Verify with Owner that maintenance service is required for Project.

A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above, to inhibit corrosion and scale formation for hydronic piping and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion and shall include the following:

1. Initial water analysis and HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
3. Periodic field service and consultation.
4. Customer report charts and log sheets.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

3.7 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

END OF SECTION 232513

SECTION 233113 - METAL DUCTS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer's products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Double-wall rectangular ducts and fittings.
3. Single-wall round[**and flat-oval**] ducts and fittings.

4. Double-wall round[**and flat-oval**] ducts and fittings.
5. Sheet metal materials.
6. Duct liner.
7. Sealants and gaskets.
8. Hangers and supports.
9. Seismic-restraint devices.

B. Related Sections:

Retain Sections in subparagraphs below that contain requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Section 233116 "Nonmetal Ducts" for fibrous-glass ducts, thermoset fiber-reinforced plastic ducts, thermoplastic ducts, PVC ducts, and concrete ducts.
3. Section 233119 "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.
4. Section 233300 "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. OSHPD: Office of Statewide Health Planning and Development (State of California).

1.4 ACTION SUBMITTALS

A. Product Data: For each type of the following products:

1. Liners and adhesives.
2. Sealants and gaskets.
3. Seismic-restraint devices.

B. Sustainable Design Submittals:

"Product Data" Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. Coordinate with requirements for adhesives.

1. Product Data: For adhesives, indicating VOC content.

"Laboratory Test Reports" Subparagraph below applies to LEED 2009 for Schools, LEED v4, IgCC, ASHRAE 189.1, and Green Globes. Coordinate with requirements for adhesives.

2. Laboratory Test Reports: For adhesives, indicating compliance with requirements for low-emitting materials.

"Product Data" Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. Coordinate with requirements for sealants.

3. Product Data: For sealants, indicating VOC content.

"Laboratory Test Reports" Subparagraph below applies to LEED 2009 for Schools, LEED v4, IgCC, ASHRAE 189.1, and Green Globes. Coordinate with requirements for sealants.

4. Laboratory Test Reports: For sealants, indicating compliance with requirements for low-emitting materials.

Retain "Laboratory Test Reports" below if factory-applied "Antimicrobial Coating" is retained under "Inside Casing Wall" Paragraph below.

"Laboratory Test Reports" Subparagraph below applies to LEED 2009 for Schools, LEED v4, IgCC, ASHRAE 189.1, and Green Globes. Coordinate with requirements for adhesives and sealants.

5. Laboratory Test Reports: For antimicrobial coatings, indicating compliance with requirements for low-emitting materials.

C. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Factory- and shop-fabricated ducts and fittings.
3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
4. Elevation of top [**and bottom**]of ducts.
5. Dimensions of [**main**] [**all**] duct runs from building grid lines.
6. Fittings.
7. Reinforcement and spacing.
8. Seam and joint construction.
9. Penetrations through fire-rated and other partitions.
10. Equipment installation based on equipment being used on Project.
11. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
12. Hangers and supports, including methods for duct and building attachment[**, seismic restraints,**] and vibration isolation.
13. <**Insert lists of areas or systems requiring Shop Drawings**>.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

D. Delegated-Design Submittal:

1. Sheet metal thicknesses.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Materials, fabrication, assembly, and spacing of hangers and supports.

Retain "Design Calculations" Subparagraph below if Work of this Section is required to withstand specific design loads and design responsibilities have been delegated to Contractor as another way to verify compliance with performance requirements. Professional engineer qualifications are specified in Section 014000 "Quality Requirements."

5. Design Calculations: Calculations[**, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation**] for selecting hangers and supports[**and seismic restraints**].

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation if products and materials by separate installers. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: A single set of plans or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.

Retain "Welding certificates" Paragraph below if retaining "Welding Qualifications" Paragraph in "Quality Assurance" Article.

B. Welding certificates.

C. Field quality-control reports.

1.6 QUALITY ASSURANCE

Retain one or more options in "Welding Qualifications" Paragraph below if shop or field welding is required. If retaining, also retain "Welding certificates" Paragraph in "Informational Submittals" Article.

A. Welding Qualifications: Qualify procedures and personnel in accordance with the following:

1. [**AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.**]
2. [**AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.**]
3. [**AWS D9.1/D9.1M, "Sheet Metal Welding Code," for duct joint and seam welding.**]

Retain "Mockups" Paragraph below for special construction. Mockups are normally required only for static-pressure classes in excess of 3-inch wg (750 Pa) when verification of maximum allowable leakage is important. If retaining, indicate location, size, and other details of mockups on Drawings and retain "Leakage Tests" Paragraph in "Field Quality Control" Article.

Consider building a mockup of typical portions of the system that can be inspected and tested early in the construction process.

B. Mockups:

1. Before installing duct systems, build mockups representing static-pressure classes in excess of [**3**] <**Insert static-pressure class**> inch wg. Build mockups to comply with the following requirements, using materials indicated for the completed Work:

a. [**Five**] <**Insert number**> transverse joints.
b. [**One**] <**Insert number**> access door(s).
c. [**Two**] <**Insert number**> typical branch connections, each with at least one elbow.
d. [**Two**] <**Insert number**> typical flexible duct or flexible-connector connections for each duct and apparatus.
e. [**One**] <**Insert number**> 90-degree turn(s) with turning vanes.
f. [**One**] <**Insert number**> fire damper(s).

g. [**One**] <**Insert number**> smoke damper(s).
h. Perform leakage tests specified in "Field Quality Control" Article. Revise mockup construction and perform additional tests as required to achieve specified minimum acceptable results.

Retain subparagraph below if mockups are installed as part of building rather than erected separately and the intention is to make an exception to the default requirement in Section 014000 "Quality Requirements" for demolishing and removing mockups when directed unless otherwise indicated.

2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

Retain "Delegated Duct Design" Paragraph below if Contractor is required to assume responsibility for duct construction design. Some jurisdictions may have more stringent requirements than SMACNA. Consult authorities having jurisdiction.

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and with performance requirements and design criteria indicated in "Duct Schedule" Article.

Retain seismic options and design criteria in "Structural Performance" Paragraph below that are approved by authorities having jurisdiction.

B. Structural Performance: Duct hangers and supports[**and seismic restraints**] shall withstand the effects of gravity[**and seismic**] loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" [**and**] [**ASCE/SEI 7**] <**Insert applicable building code**>. [**Seismically brace duct hangers and supports in accordance with**] [**SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."**] [**SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems - OSHPD Edition."**] <**Insert reference document.**>

Retain "Seismic Hazard Level (SHL)" and "Connection Level" subparagraphs and one of options below if retaining SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems" or SMACNA's "Seismic Restrain Manual: Guidelines for Mechanical Systems - OSHPD Edition" option in "Structural Performance" Paragraph above. If using other seismic design criteria, delete first two subparagraphs below and insert applicable requirement. First and second SHL options below are only options available in the OSHPD Edition version.

1. Seismic Hazard Level (SHL): [**AA**] [**A**] [**B**] [**C**] [**D**].

Retain "Connection Level" Subparagraph below for OSHPD jurisdiction.

2. Connection Level: [**1**] [**2**].
3. <**Insert requirement**>.

Retain "Airstream Surfaces," "ASHRAE Compliance," or "ASHRAE/IES Compliance" Paragraph below to comply with sustainable design schemes that require compliance with ASHRAE 62.1 and ASHRAE/IES 90.1.

C. Airstream Surfaces: Surfaces in contact with airstream shall comply with requirements in ASHRAE 62.1.

D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment," and Section 7 - "Construction and System Startup."

E. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

F. Duct Dimensions: Unless otherwise indicated, all duct dimensions indicated on Drawings are inside clear dimensions and do not include insulation or duct wall thickness.

2.2 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

See "Static-Pressure Classes" and "Leakage and Seal Classes" articles in the Evaluations for discussion on fabrication.

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

1. Construct ducts of galvanized sheet steel unless otherwise indicated.
2. For ducts exposed to weather, construct of [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

B. Transverse Joints: Fabricate joints in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. For ducts with longest side less than 36 inches, select joint types in accordance with Figure 2-1.
2. For ducts with longest side 36 inches or greater, use flange joint connector Type T-22, T-24, T-24A, T-25a, or T-25b. Factory-fabricated flanged duct connection system may be used if submitted and approved by engineer of record.
3. [**Where specified for specific applications, all joints shall be welded.**]

C. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."[**All longitudinal seams shall be Pittsburgh lock seams unless otherwise specified for specific application.**]

1. [**Where specified for specific applications, all joints shall be welded.**]

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 DOUBLE-WALL RECTANGULAR DUCTS AND FITTINGS

Retain manufacturer list to require factory-fabricated, double-wall rectangular ducts and fittings; delete to allow shop-fabricated ducts and fittings.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Rectangular Ducts: Fabricate ducts with indicated dimensions for clear internal dimensions of the inner duct.

C. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

1. Construct ducts of galvanized sheet steel unless otherwise indicated.
2. For ducts exposed to weather, construct outer duct of [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

D. Transverse Joints: Select joint types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. For ducts with longest side less than 36 inches, select joint types in accordance with Figure 2-1.
2. For ducts with longest side 36 inches or greater, use flange joint connector Type T-22, T-24, T-24A, T-25a, or T-25b. Factory-fabricated flanged duct connection system may be used if submitted and approved by engineer of record.
3. [**Where specified for specific applications, all joints shall be welded.**]

E. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."[**All longitudinal seams shall be Pittsburgh lock seams unless otherwise specified for specific application.**]

1. [**Where specified for specific applications, all joints shall be welded.**]

Retain one of two "Interstitial Insulation" paragraphs below. If the objective of interstitial insulation includes achievement of both thermal performance and sound absorption, then ducts may need additional external insulation to achieve the thermal portion of the objective. See Section 230713 "Duct Insulation" for applicable duct insulation and installation requirements for external duct application.

F. Interstitial Insulation: Fibrous-glass liner complying with ASTM C1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

Retain "Maximum Thermal Conductivity" Subparagraph below to require thermal conductivity exceeding requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

1. Maximum Thermal Conductivity: [**0.27 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
3. Coat insulation with antimicrobial coating.

Retain subparagraph below for additional protection of airstream.

4. Cover insulation with polyester film complying with UL 181, Class 1.

G. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C534/C534M, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

Retain "Maximum Thermal Conductivity" Subparagraph below to require thermal conductivity exceeding requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

1. Maximum Thermal Conductivity: [**0.25 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.

H. Inner Duct: Minimum 24-gauge [**perforated galvanized sheet steel having 3/32-inch-diameter perforations, with overall open area of 23 percent**] [**solid galvanized sheet steel**].

2.4 SINGLE-WALL ROUND[**AND FLAT-OVAL**] DUCTS AND FITTINGS

See "Static-Pressure Classes" and "Leakage and Seal Classes" articles in the Evaluations for discussion on fabrication.

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

1. Construct ducts of galvanized sheet steel unless otherwise indicated.
2. For ducts exposed to weather, construct of [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

Retain manufacturer list to require factory-fabricated, single-wall round and flat-oval ducts and fittings; delete to allow shop-fabricated ducts and fittings.

3. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).

C. Transverse Joints: Select joint types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Option in subparagraph below is SMACNA's requirement. Insert smaller dimension for more stringent requirement.

1. Transverse Joints in Ducts Larger Than [**60**] <**Insert dimension**> Inches in Diameter: Flanged.

D. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

E. Tees and Laterals: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.5 DOUBLE-WALL ROUND[**AND FLAT-OVAL**] DUCTS AND FITTINGS

Retain manufacturer list to require factory-fabricated, double-wall round and flat-oval ducts and fittings; delete to allow shop-fabricated ducts and fittings.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct.

1. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.

   a. Construct ducts of galvanized sheet steel unless otherwise indicated.
   b. For ducts exposed to weather, construct outer duct of [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.

2. Transverse Joints: Select joint types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Option in subparagraph below is SMACNA's requirement. Insert smaller dimension for more stringent requirement.

   a. Transverse Joints in Ducts Larger Than [**60**] <**Insert dimension**> Inches in Diameter: Flanged.

3. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

   a. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
   b. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

4. Tees and Laterals: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Inner Duct: Minimum 24-gauge [**perforated galvanized sheet steel having 3/32-inch-diameter perforations, with overall open area of 23 percent**] [**solid galvanized sheet steel**].

Retain one of two "Interstitial Insulation" paragraphs below. If the objective of interstitial insulation includes achievement of both thermal performance and sound absorption, then ducts may need additional external insulation to achieve the thermal portion of the objective. See Section 230713 "Duct Insulation" for applicable duct insulation and installation requirements for external duct application.

D. Interstitial Insulation: Fibrous-glass liner complying with ASTM C1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

Retain "Maximum Thermal Conductivity" Subparagraph below to require thermal conductivity exceeding requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

1. Maximum Thermal Conductivity: [**0.27 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.
2. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
3. Coat insulation with antimicrobial coating.
4. Cover insulation with polyester film complying with UL 181, Class 1.

E. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C534/C534M, Type II for sheet materials, and with NFPA 90A or NFPA 90B.

Retain "Maximum Thermal Conductivity" Subparagraph below to require thermal conductivity exceeding requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

1. Maximum Thermal Conductivity: [**0.25 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.

2.6 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

See "Sheet Metal Materials" Article in the Evaluations for discussion on applicable materials and coatings in "Galvanized Sheet Steel"; "PVC-Coated, Galvanized Sheet Steel"; "Carbon-Steel Sheets"; "Stainless-Steel Sheets"; and "Aluminum Sheets" paragraphs below.

B. Galvanized Sheet Steel: Comply with ASTM A653/A653M.

1. Galvanized Coating Designation: [**G60**] [**G90**].
2. Finishes for Surfaces Exposed to View: Mill phosphatized.

C. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A653/A653M.

1. Galvanized Coating Designation: [**G60**] [**G90**].

Most sheet metal suppliers can provide a 4-mil- (0.10-mm-) thick coating on both sides.

2. Minimum Thickness for Factory-Applied PVC Coating: 4 mils thick[**on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil thick on opposite surface**].
3. Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.

D. Carbon-Steel Sheets: Comply with ASTM A1008/A1008M, with oiled, matte finish for exposed ducts.

E. Stainless-Steel Sheets: Comply with ASTM A480/A480M, Type 304 or 316, as indicated in "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in "Duct Schedule" Article.

F. Aluminum Sheets: Comply with ASTM B209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

Antimicrobial coating in "Factory- or Shop-Applied Antimicrobial Coating" Paragraph below is an optional feature and usually applied only after fabrication to ducts fabricated with galvanized sheet steel. See the Evaluations for discussion on coatings.

G. Factory- or Shop-Applied Antimicrobial Coating:

1. Apply to the surface of sheet metal that will form the interior surface of the duct. An untreated clear coating shall be applied to the exterior surface.
2. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Coating containing the antimicrobial compound shall have a hardness of 2H, minimum, when tested in accordance with ASTM D3363.
4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.
5. Shop-Applied Coating Color: [**Black**] [**White**].
6. Antimicrobial coating on sheet metal is not required for duct containing liner treated with antimicrobial coating.

H. Reinforcement Shapes and Plates: ASTM A36/A36M, steel plates, shapes, and bars; black and galvanized.

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

I. Tie Rods: Galvanized steel, 1/4-inch-minimum diameter for lengths 36 inches or less; 3/8-inch-minimum diameter for lengths longer than 36 inches.

2.7 DUCT LINER

If the objective of duct liner includes achievement of both thermal performance and sound absorption, then ducts may need additional external insulation to achieve the thermal portion of the objective. See Section 230713 "Duct Insulation" for applicable duct insulation and installation requirements for external duct application.

Sustainable design schemes require that duct insulation R-value comply with ASHRAE/IES 90.1 tables titled "Minimum Duct Insulation R-Value." If using liner alone to satisfy thermal requirements, verify that material selected is available in thickness needed to provide thermal performance without jeopardizing other requirements.

Type I duct liner is available in thicknesses of 1/2 to 2 inches (13 to 50 mm) in 1/2-inch (13-mm) increments; Type II duct liner is available in thicknesses of 1 to 2 inches (25 to 50 mm) in 1/2-inch (13-mm) increments. Indicate thicknesses on Drawings or in "Duct Schedule" Article.

When specifying duct liner by referencing ASTM C1071, specifiers are assured of product qualifications for corrosiveness, water-vapor sorption, fungi resistance, temperature resistance, erosion resistance, odor emission, surface-burning characteristics, apparent thermal conductivity, sound absorption coefficients, bacteria resistance, and combustion characteristics.

A. Fibrous-Glass Duct Liner: Comply with ASTM C1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain "Maximum Thermal Conductivity" Subparagraph below to require thermal conductivity exceeding minimum requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification.

2. Maximum Thermal Conductivity:

Option for thermal conductivity in first two subparagraphs below exceeds values in ASTM C1071. If retaining, verify availability of performance with duct liner manufacturers.

a. Type I, Flexible: [**0.27 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.
b. Type II, Rigid: [**0.23 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature.

Antimicrobial coating in "Antimicrobial Erosion-Resistant Coating" Subparagraph below is an optional feature for duct liner.

3. Antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
4. [**Solvent**] [**Water**]-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C916.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. VOC content limit is that for fiberglass.

a. Adhesive shall have a VOC content of 80 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

b. Adhesive shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

Duct liner in "Flexible Elastomeric Duct Liner" Paragraph below is not suitable for temperatures higher than 220 deg F (104 deg C).

B. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C534/C534M, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Available thicknesses for flexible elastomeric duct liner are 3/8, 1/2, 3/4, and 1 inch (10, 13, 19, and 25 mm). Indicate thickness on Drawings or in "Duct Schedule" Article.

Characteristics in "Surface-Burning Characteristics" Subparagraph below are available in limited thicknesses. Verify maximum thickness with manufacturers.

2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.

3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. VOC content limit is that for contact adhesive.

a. Adhesive shall have a VOC content of 80 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

b. Adhesive shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

C. Fiberglass-Free Duct Liner: Made from partially recycled cotton or polyester products and containing no fiberglass. Airstream surface overlaid with fire-resistant facing to prevent surface erosion by airstream, complying with NFPA 90A or NFPA 90B. Treat natural-fiber products with antimicrobial coating.

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Available thicknesses for natural-fiber duct liner are 1/2 and 1 inch (13 and 25 mm). Indicate thickness on Drawings or in "Duct Schedule" Article.

2. Maximum Thermal Conductivity: [**0.24 Btu x in./h x sq. ft. x deg F**] <**Insert conductivity**> at 75 deg F mean temperature when tested in accordance with ASTM C518.
3. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested in accordance with ASTM E84; certified by an NRTL.
4. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes. VOC content limit is that for contact adhesive.

a. Adhesive shall have a VOC content of 80 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

b. Adhesive shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

D. Insulation Pins and Washers:

1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, [**0.106-inch-**] [**0.135-inch-**] diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.

2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick [**galvanized steel**] [**aluminum**] [**stainless steel**]; with beveled edge sized as required to hold insulation securely in place, but not less than 1-1/2 inches in diameter.

E. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
3. Butt transverse joints without gaps, and coat joint with adhesive.
4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
5. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.

Delete first subparagraph below if air velocities do not exceed 2500 fpm (12.7 m/s).

6. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpmor greater.

Securing method in first subparagraph below is for ducts with air velocities of 2500 fpm (12.7 m/s) and lower. Use caution when designing lined ducts with air velocities higher than 2500 fpm (12.7 m/s). See SMACNA for requirements.

7. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally.
8. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:

    a. Fan discharges.
    b. Intervals of lined duct preceding unlined duct.
    c. Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm or where indicated.

Retain first subparagraph below if ducts with air velocities higher than 4000 fpm (20.3 m/s) are anticipated; indicate locations of double-wall ducts on Drawings. Use solid-metal (unperforated) inner ducts for material-handling exhaust systems.

9. Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compressing insulation.

    a. Sheet Metal Inner Duct Perforations: 3/32-inch diameter, with an overall open area of 23 percent.

10. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other

buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

2.8 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.

See SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for discussion on seam and joint sealing methods and their applications. Retain one or more of "Two-Part Tape Sealing System," "Water-Based Joint and Seam Sealant," and "Solvent-Based Joint and Seam Sealant" paragraphs below; identify which sealing system applies to which duct system in "Duct Schedule" Article.

B. Two-Part Tape Sealing System:

1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
2. Tape Width: [**3 inches**] [**4 inches**] [**6 inches**].
3. Sealant: Modified styrene acrylic.
4. Water resistant.
5. Mold and mildew resistant.
6. Maximum Static-Pressure Class: 10 inch wg, positive and negative.
7. Service: Indoor and outdoor.
8. Service Temperature: Minus 40 to plus 200 deg F.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes.

10. Sealant shall have a VOC content of 420 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

11. Sealant shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

Retain "Water-Based Joint and Seam Sealant" or "Solvent-Based Joint and Seam Sealant" Paragraph below. If retaining second paragraph, verify acceptability with authorities having jurisdiction.

C. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).

7. Maximum Static-Pressure Class: 10 inch wg, positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Solvent-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Base: Synthetic rubber resin.
3. Solvent: Toluene and heptane.
4. Solids Content: Minimum 60 percent.
5. Shore A Hardness: Minimum 60.
6. Water resistant.
7. Mold and mildew resistant.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes.

8. Sealant shall have a VOC content of 420 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

9. Sealant shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
10. Maximum Static-Pressure Class: 10-inch wg, positive or negative.
11. Service: Indoor or outdoor.
12. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

E. Flanged Joint Sealant: Comply with ASTM C920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.

Subparagraph below applies to LEED 2009 NC, CI, and CS; LEED v4; IgCC; ASHRAE 189.1; and Green Globes.

6. Sealant shall have a VOC content of 420 g/L or less.

Subparagraph below applies to LEED 2009 for Schools Credit IEQ 4.1.

7. Sealant shall comply with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

F. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

O-ring seals are generally available for duct fittings 3 to 24 inches (76 to 610 mm) in diameter.

G. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for10-inch wg static-pressure class, positive or negative.

Retain one or both subparagraphs below. These are proprietary seals provided on factory-fabricated, round duct fitting joints and constructed with specific dimensions to ensure a proper seal.

2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.9 HANGERS AND SUPPORTS

Indicate extent of corrosive environment on Drawings.

A. Hanger Rods for Noncorrosive Environments: Galvanized-steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A603.

E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A492.

F. Steel Cable End Connections: Galvanized-steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

H. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

2.10 SEISMIC-RESTRAINT DEVICES

Coordinate specifications for seismic-restraint components in this article with structural engineer and with Drawings. See "Seismic Considerations" Article in the Evaluations for discussion on seismic restraints.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

See the Evaluations in Section 230548 "Vibration and Seismic Controls for HVAC" for discussion on seismic-restraint capacities and rating services.

B. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by [**an evaluation service member of the ICC Evaluation Service**] [**OSHPD, in State of California**] [**an agency acceptable to authorities having jurisdiction**].

1. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least [**four**] <**Insert number**> times the maximum seismic forces to which they will be subjected.

C. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.

D. Restraint Cables: [**ASTM A603, galvanized**] [**ASTM A492, stainless**]-steel cables with end connections made of galvanized-steel assemblies with brackets, swivel, and bolts designed for restraining cable service; and with an automatic-locking and clamping device or double-cable clips.

Retain "Hanger Rod Stiffener" Paragraph below for strengthening resistance of hanger rods against seismic forces that may cause rods to buckle. Use with either channel- or cable-type bracing assemblies. Detail fabrication and indicate locations on Drawings.

E. Hanger Rod Stiffener: [**Steel tube or steel slotted-support-system sleeve with internally bolted connections**] [**Reinforcing steel angle clamped**] to hanger rod.

F. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested in accordance with ASTM E488/E488M.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

Coordinate duct layout and duct accessory arrangement with Drawings.

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and coordination drawings.

B. Install ducts in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install ducts in maximum practical lengths with fewest possible joints.

D. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

E. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

F. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

G. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

H. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

I. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

J. Install fire[**, combination fire/smoke,**] and smoke dampers where indicated on Drawings and as required by code, and by local authorities having jurisdiction. Comply with requirements in Section 233300 "Air Duct Accessories" for fire and smoke dampers and specific installation requirements of the damper UL listing.

K. Install heating coils, cooling coils, air filters, dampers, and all other duct-mounted accessories in air ducts where indicated on Drawings.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials both before and after installation.[**Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."**]

M. Elbows: Use long-radius elbows wherever they fit.

1. Fabricate 90-degree rectangular mitered elbows to include turning vanes.
2. Fabricate 90-degree round elbows with a minimum of three segments for 12 inches and smaller and a minimum of five segments for 14 inches and larger.

N. Branch Connections: Use lateral or conical branch connections.

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 ADDITIONAL INSTALLATION REQUIREMENTS FOR TYPE 1 COMMERCIAL KITCHEN GREASE HOOD EXHAUST DUCT

A. Install ducts in accordance with NFPA 96, "Ventilation Control and Fire Protection of Commercial Cooking Operation"; SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; and SMACNA's "Kitchen Ventilation Systems and Food Service Equipment Fabrication and Installation Guidelines" unless otherwise indicated.

B. Install all ducts without dips and traps that may hold grease, and sloped a minimum of 2 percent to drain grease back to the hood.

C. All ducts exposed to view shall be constructed of stainless steel as per "Duct Schedule" Article. All ducts concealed from view shall be [**stainless**] [**carbon**] steel as per "Duct Schedule" Article.

D. All joints shall be welded and shall be telescoping, bell, or flange joint as per NFPA 96.

E. Install fire-rated access panel assemblies at each change in direction and at maximum intervals of [**20**] [**12**] <**Insert dimension**> feet in horizontal ducts, and at every floor for vertical ducts, or as indicated on Drawings.

F. Do not penetrate fire-rated assemblies except as allowed by applicable building codes and authorities having jurisdiction.

3.4 ADDITIONAL INSTALLATION REQUIREMENTS FOR EXHAUST DUCTS SERVING COMMERCIAL DISHWASHERS AND OTHER HIGH-HUMIDITY LOCATIONS

A. Install dishwasher exhaust ducts and other exhaust ducts from wet, high-humidity locations without dips and traps that may hold water. Slope ducts a minimum of 2 percent back to dishwasher or toward drain.

B. Provide a drain pocket at each low point and at the base of each riser with a 1-inchtrapped copper drain from each drain pocket to open site floor drain.

C. Minimize number of transverse seams.

D. Do not locate longitudinal seams on bottom of duct.

3.5 ADDITIONAL INSTALLATION REQUIREMENTS FOR LABORATORY EXHAUST AND FUME HOOD EXHAUST DUCTS

A. Install ducts in accordance with NFPA 45, "Fire Protection for Laboratories Using Chemicals."

B. Install exhaust ducts without dips and traps that may hold water. Slope ducts a minimum of 2 percent back to hood or inlet. Where indicated on Drawings, install trapped drain piping.

C. Connect duct to fan, fume hood, and other equipment indicated on Drawings.

3.6 DUCTWORK EXPOSED TO WEATHER

A. All external joints are to [**be welded**] [**have secure watertight mechanical connections**]. Seal all openings to provide weatherproof construction.

B. Construct ductwork to resist external loads of wind, snow, ice, and other effects of weather. Provide necessary supporting structures.

C. Single Wall:

Retain one of first two subparagraphs below.

1. Ductwork shall be [**Type 304**] [**Type 316**] stainless steel.
2. Ductwork shall be galvanized steel.

    a. If duct outer surface is uninsulated, protect outer surface with suitable paint. Paint materials and application requirements are specified in Section 099113 "Exterior Painting."

3. Where ducts have external insulation, provide weatherproof aluminum jacket. See Section 230713 "Duct Insulation."

D. Double Wall:

1. Ductwork shall comply with requirements in "Double-Wall Rectangular Ducts and Fittings" or "Double-Wall Round [**and Flat-Oval**]Ducts and Fittings" Article.
2. Ductwork outer wall shall be [**Type 304**] [**Type 316**] stainless steel indicated by manufacturer to be suitable for outdoor installation.
3. Provide interstitial insulation.

3.7 DUCT SEALING

Retain one of two paragraphs below. Retain first paragraph if retaining subparagraphs for seal class and leakage class in "Duct Schedule" Article; otherwise, delete first and retain second paragraph.

A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

Retain paragraph below for compliance with ASHRAE/IES 90.1, in which Section 6.4.4.2.1 - "Duct Sealing" requires a minimum seal class for various duct locations and pressures indicated in paragraph.

B. Seal ducts at a minimum to the following seal classes in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":

1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
2. Outdoor, Supply-Air Ducts: Seal Class A.
3. Outdoor, Exhaust Ducts: Seal Class C.

4. Outdoor, Return-Air Ducts: Seal Class C.
5. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class B.
6. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
7. Unconditioned Space, Exhaust Ducts: Seal Class C.
8. Unconditioned Space, Return-Air Ducts: Seal Class B.
9. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class C.
10. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class B.
11. Conditioned Space, Exhaust Ducts: Seal Class B.
12. Conditioned Space, Return-Air Ducts: Seal Class C.

3.8 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

Verify attachment selection and spacing in "Building Attachments" and "Hanger Spacing" paragraphs below with structural engineer.

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.

Retain subparagraph below for projects that require seismic restraints.

5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.9 SEISMIC-RESTRAINT-DEVICE INSTALLATION

A. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with [**SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."**] [**SMACNA's "Seismic Restrain Manual: Guidelines for Mechanical Systems - OSHPD Edition."**] [**ASCE/SEI 7.**]

Options for 40 and 80 feet (12 and 24 m) in first subparagraph below are recommended by SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems." Revise these dimensions based on the configuration of duct and the seismic hazard.

1. Space lateral supports a maximum of [**40**] <**Insert dimension**> feet o.c., and longitudinal supports a maximum of [**80**] <**Insert dimension**> feet o.c.
2. Brace a change of direction longer than 12 feet.

B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.

C. Install cables so they do not bend across edges of adjacent equipment or building structure.

D. Install cable restraints on ducts that are suspended with vibration isolators.

E. Install seismic-restraint devices using methods approved by [**an evaluation service member of the ICC Evaluation Service**] [**OSHPD**] [**an agency acceptable to authorities having jurisdiction**].

F. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.

G. Drilling for and Setting Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Set anchors to manufacturer's recommended torque, using a torque wrench.
5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.10 CONNECTIONS

Coordinate duct installations and specialty arrangements with Drawings.

A. Make connections to equipment with flexible connectors complying with Section 233300 "Air Duct Accessories."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.11 PAINTING

A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

3.12 FIELD QUALITY CONTROL

A. Perform tests and inspections.

Retain "Leakage Tests" Paragraph below for ducts in pressure classes 3-inch wg (750 Pa) and higher or if applying for sustainable design certification. It may not be economically practical to test ducts in pressure classes less than 3-inch wg (750 Pa).

B. Leakage Tests:

1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
2. Test the following systems:

Sustainable design requiring compliance with ASHRAE/IES 90.1 must comply with requirements of Section 6.4.4.2.2 - "Duct Leakage Tests," which requires leak testing of at least 25 percent of total installed duct area with a pressure class in excess of 3-inch wg (750 Pa). Retain "Ducts with a Pressure Class Higher Than 3-Inch wg (750 Pa)" Subparagraph below for minimum requirements if applying for sustainable design certification or complying with ASHRAE/IES 90.1. To define more stringent requirements, retain subsequent subparagraphs as applicable and delete "Ducts with a Pressure Class Higher Than 3-Inch wg (750 Pa)" Subparagraph. Consider cost impact when specifying extent of duct area to be tested. It is not common to leak test all ducts or ducts with a pressure class less than 3-inch wg (750 Pa).

a. Ducts with a Pressure Class Higher Than 3-Inch wg: Test representative duct sections[**, selected by Architect from sections installed,**] totaling no less than 25 percent of total installed duct area for each designated pressure class.
b. Supply Ducts with a Pressure Class of [**2-**] [**3-**] [**4-**] <**Insert number**> Inch wg or Higher: Test representative duct sections[**, selected by Architect from sections installed,**] totaling no less than [**50**] [**100**] <**Insert number**> percent of total installed duct area for each designated pressure class.
c. Return Ducts with a Pressure Class of [**2-**] [**3-**] [**4-**] <**Insert number**> Inch wg or Higher: Test representative duct sections[**, selected by Architect from sections installed,**] totaling no less than [**50**] [**100**] <**Insert number**> percent of total installed duct area for each designated pressure class.

d. Exhaust Ducts with a Pressure Class of [**2-**] [**3-**] [**4-**] <**Insert number**> Inch wg or Higher: Test representative duct sections[**, selected by Architect from sections installed,**] totaling no less than [**50**] [**100**] <**Insert number**> percent of total installed duct area for each designated pressure class.
e. Outdoor-Air Ducts with a Pressure Class of [**2-**] [**3-**] [**4-**] <**Insert number**> Inch wg or Higher: Test representative duct sections[**, selected by Architect from sections installed,**] totaling no less than [**50**] [**100**] <**Insert number**> percent of total installed duct area for each designated pressure class.

3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
4. Testing of each duct section is to be performed with access doors, coils, filters, dampers, and other duct-mounted devices in place as designed. No devices are to be removed or blanked off so as to reduce or prevent additional leakage.
5. Test for leaks before applying external insulation.
6. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
7. Give [**seven**] <**Insert number**> days' advance notice for testing.

Retain "Duct System Cleanliness Tests" Paragraph below if duct cleaning is required or if applying for sustainable design certification. Sustainable design requiring compliance with ASHRAE 62.1 must comply with requirements of Section 7.2.4 - "Ventilation System Start-up," which requires that distribution systems be clean of dirt and debris. Text was taken from NADCA ACR, dated 2013.

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness in accordance with "Description of Method 3 - NADCA Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.13 DUCT CLEANING

Retain this article for applications where construction dust and debris in duct system must be removed before air-system operation, or if applying for sustainable design certification.

Sustainable design requiring compliance with ASHRAE 62.1 must comply with requirements of Section 7.2.4 - "Ventilation System Start-up," which requires that distribution systems be clean of dirt and debris.

This Section includes cleaning of new ductwork only. Where a project requires cleaning of portions of an existing duct system as well as all new work, those portions of existing system requiring cleaning must be accurately identified. This action is best done by indicating on a floor plan the duct portions to be cleaned. If cleaning of existing systems is required, include Section 230130.52 "Existing HVAC Air Distribution System Cleaning."

A. Clean new duct system(s) before testing, adjusting, and balancing.

B. For cleaning of existing ductwork, see Section 230130.52 "Existing HVAC Air Distribution System Cleaning."

C. Use duct cleaning methodology as indicated in NADCA ACR.

D. Use service openings for entry and inspection.

1. Provide openings with access panels appropriate for duct static-pressure and leakage class at dampers, coils, and any other locations where required for inspection and cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Section 233300 "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

E. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

F. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

G. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.

2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans in accordance with NADCA ACR. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents in accordance with manufacturer's written instructions after removal of surface deposits and debris.

3.14 STARTUP

Sustainable design requiring compliance with ASHRAE 62.1 should be coordinated with requirements of Section 7 - "Construction and System Start-up."

A. Air Balance: Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.15 DUCT SCHEDULE

A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

1. Fabricate all ducts to achieve SMACNA pressure class, seal class, and leakage class as indicated below.
2. Underground Ducts: Concrete-encased, [**galvanized sheet steel**] [**PVC-coated, galvanized sheet steel with thicker coating on duct exterior**] [**stainless steel**].
3. <**Insert requirements**>.

Retain applicable subparagraphs in this article to set criteria for pressure class, duct seal-class level, and duct-leakage class; or delete subparagraphs and indicate pressure class, duct seal-class level, and duct-leakage class on Drawings. If retaining duct seal and leakage requirements in this article, retain first paragraph in "Duct Sealing" Article. Both seal class and leakage class are included in this article and either one can be deleted, or both can remain if they are consistent.

Paragraphs below are examples of broad system classifications. Revise to suit Project or indicate requirements on Drawings if a more refined classification is required.

See ASHRAE duct leakage recommendations in 2016 ASHRAE HANDBOOK - "HVAC Systems and Equipment," Ch. 19, "Duct Construction."

Sustainable design requiring compliance with ASHRAE/IES 90.1 must comply with requirements of Section 6.4.4.2.1 - "Duct Sealing," which requires a minimum seal-class level (A, B, or C) for various duct locations and pressures and specifies seal-class levels for joints and seams in ducts located outdoors, in unconditioned spaces, and in conditioned spaces. Retain second paragraph in "Duct Sealing" Article if applying for sustainable design certification and requirements are not defined in this article or indicated on Drawings.

B. Supply Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <**Insert equipment**>:

a. Pressure Class: Positive [**1-**] [**2-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

2. Ducts Connected to Constant-Volume Air-Handling Units <**Insert equipment**>:

a. Pressure Class: Positive [**2-**] [**3-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**].
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

3. Ducts Connected to Variable-Air-Volume Air-Handling Units <**Insert equipment**>:

a. Pressure Class: Positive [**3-**] [**4-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**].
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

4. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

C. Return Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <**Insert equipment**>:

a. Pressure Class: Positive or negative [**1-**] [**2-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

2. Ducts Connected to Air-Handling Units <**Insert equipment**>:

a. Pressure Class: Positive or negative [**2-**] [**3-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

3. Ducts Connected to Equipment Not Listed above:

   a. Pressure Class: Positive or negative [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.
   b. Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].
   c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
   d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

D. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:

   a. Pressure Class: Negative [**1-**] [**2-**] [**3-**] <**Insert number**>inch wg.
   b. Minimum SMACNA Seal Class: [**A**] [**B**] [**C**] if negative pressure, and A if positive pressure.
   c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
   d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

2. Ducts Connected to Air-Handling Units <**Insert equipment**>:

   a. Pressure Class: Positive or negative [**2-**] [**3-**] <**Insert number**>inch wg.
   b. Minimum SMACNA Seal Class: [**A**] [**B**] [**C**] if negative pressure, and [**A**] [**B**] [**C**] if positive pressure.
   c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
   d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

3. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.

   a. Exposed to View: Type 304, stainless-steel sheet, [**No. 4**] [**No. 3**] <**Insert finish**> finish.
   b. Concealed: [**Type 304, stainless-steel sheet, No. 2D finish**] [**Carbon-steel sheet**].
   c. Welded seams and joints.
   d. Pressure Class: Positive or negative [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.
   e. Airtight/watertight.

4. Ducts Connected to Dishwashers, Dishwasher Hoods, and Other High-Humidity Locations:

   a. Type 304, stainless-steel sheet.
   b. Exposed to View: [**No. 4**] [**No. 3**] <**Insert finish**> finish.
   c. Concealed: [**No. 2D**] <**Insert finish**> finish.
   d. Welded longitudinal seams; welded or flanged transverse joints with watertight EPDM gaskets.
   e. Pressure Class: Positive or negative [**2-**] [**3-**] <**Insert number**>inch wg.
   f. Airtight/watertight.

5. Ducts Connected to Fans Exhausting Fume Hood, Laboratory, and Process (ASHRAE 62.1, Class 3 and Class 4) Air:

Retain one of first two subparagraphs below. Determine from system users what chemicals are to be exhausted; verify suitable exhaust duct materials. Also consider Section 233116 "Nonmetal Ducts."

a. [**Type 316**] [**Type 304**], stainless-steel sheet.

1) Exposed to View: [**No. 4**] [**No. 3**] <**Insert finish**> finish.
2) Concealed: [**No. 2B**] [**No. 2D**] <**Insert finish**> finish.

b. PVC-coated, galvanized sheet steel with thicker coating on duct interior.
c. Pressure Class: Positive or negative [**3-**] [**4-**] [**6-**] <**Insert number**>inch wg.
d. [**Minimum SMACNA Seal Class A**] [**Welded seams and joints**].

Retain "SMACNA Leakage Class 2" Subparagraph below if retaining "Minimum SMACNA Seal Class A" option in last subparagraph above. Retain "Airtight/watertight" Subparagraph below if retaining "Welded seams and joints" option above.

e. [**SMACNA Leakage Class 2.**]
f. [**Airtight/watertight.**]

6. Ducts Connected to Equipment Not Listed above:

a. Pressure Class: Positive or negative [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**] if negative pressure; A if positive pressure.
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units <**Insert equipment**>:

a. Pressure Class: Positive or negative [**1-**] [**2-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**] [**C**].
c. SMACNA Leakage Class for Rectangular: [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**8**] [**16**].

2. Ducts Connected to Air-Handling Units <**Insert equipment**>:

a. Pressure Class: Positive or negative [**2-**] [**3-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**].
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

3. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive or negative [**2-**] [**3-**] [**4-**] <**Insert number**>inch wg.
b. Minimum SMACNA Seal Class: [**A**] [**B**].
c. SMACNA Leakage Class for Rectangular: [**2**] [**4**] [**8**] [**16**].
d. SMACNA Leakage Class for Round and Flat Oval: [**2**] [**4**] [**8**] [**16**].

F. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: [**Galvanized steel**] [**Carbon steel coated with zinc-chromate primer**] [**Galvanized steel or carbon steel coated with zinc-chromate primer**].

2. PVC-Coated Ducts:

    a. Exposed to Airstream: Match duct material.
    b. Not Exposed to Airstream: [**Galvanized**] [**Match duct material**].

3. Stainless-Steel Ducts:

    a. Exposed to Airstream: Match duct material.
    b. Not Exposed to Airstream: [**Galvanized**] [**Match duct material**].

4. Aluminum Ducts: [**Aluminum**] [**or**] [**galvanized steel coated with zinc chromate**].

G. Liner:

Sustainable design requiring compliance with ASHRAE/IES 90.1 must have duct insulation with an R-value that complies with tables titled "Minimum Duct Insulation R-Value, Cooling and Heating Only Supply Ducts and Return Ducts" and "Minimum Duct Insulation R-Value, Combined Heating and Cooling Supply Ducts and Return Ducts." If using liner alone to satisfy thermal requirements, verify that material selected is available in thickness needed to provide thermal performance without jeopardizing other requirements.

Flexible elastomeric insulation is available in thicknesses through 1-1/2 inches (38 mm), which comply with NFPA 90A. Some options in subparagraphs below may create a restrictive proprietary specification. Verify availability of performance with manufacturers.

Retain one option for material and one option for thickness, or insert another thickness, in each of six subparagraphs below.

1. Supply-Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es thick.
2. Return-Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es thick.
3. Exhaust-Air Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] <**Insert dimension**> inch(es thick.
4. Supply Fan Plenums: [**Fibrous glass, Type II**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es thick.
5. Return- and Exhaust-Fan Plenums: [**Fibrous glass, Type II**] [**Flexible elastomeric**] [**Natural fiber**], [**2**] <**Insert dimension**> inches thick.
6. Transfer Ducts: [**Fibrous glass, Type I**] [**Flexible elastomeric**] [**Natural fiber**], [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es thick.

Sustainable design requiring compliance with ASHRAE/IES 90.1 must have duct insulation with an R-value that complies with tables titled "Minimum Duct Insulation R-Value, Cooling and Heating Only Supply Ducts and Return Ducts" and "Minimum Duct Insulation R-Value, Combined Heating and Cooling Supply Ducts and Return Ducts." If using interstitial insulation alone to satisfy thermal requirements, verify that material selected is available in thickness needed to provide thermal performance without jeopardizing other requirements.

H. Double-Wall Duct Interstitial Insulation:

1. Supply-Air Ducts: [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es thick.

2. Return-Air Ducts: [**1**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es thick.
3. Exhaust-Air Ducts: [**1h**] [**1-1/2**] [**2**] <**Insert dimension**> inch(es thick.

I. Elbow Configuration:

Retain one of two "Rectangular Duct" subparagraphs below. Retain first subparagraph to set different requirements for various velocities; second, to set the same requirements for all velocities.

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

   a. Velocity 1000 fpm or Lower:

      1) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.
      2) Mitered Type RE 4 without vanes.

   b. Velocity 1000 to 1500 fpm:

      1) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.
      2) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.
      3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

   c. Velocity 1500 fpm or Higher:

      1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
      2) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
      3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

2. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

   a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
   b. Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
   c. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

3. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

   a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.

Retain "Velocity 1000 fpm (5 m/s) or Lower," "Velocity 1000 to 1500 fpm (5 to 7.6 m/s)," and "Velocity 1500 fpm (7.6 m/s) or Higher" subparagraphs below, or delete all and retain "Radius-to Diameter Ratio" Subparagraph.

1) Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
2) Velocity 1000 to 1500 fpm: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
3) Velocity 1500 fpm or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
4) Radius-to Diameter Ratio: 1.5.

b. Round Elbows, [**12**] <**Insert dimension**> Inches and Smaller in Diameter: Stamped or pleated.
c. Round Elbows, [**14**] <**Insert dimension**> Inches and Larger in Diameter: [**Standing seam**] [**Welded**].

Delete "Branch Configuration" Paragraph below if branch fittings are indicated on Drawings.

J. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

a. Rectangular Main to Rectangular Branch: 45-degree entry.
b. Rectangular Main to Round Branch: Conical spin in.

2. Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

a. Velocity 1000 fpm or Lower: 90-degree tap.
b. Velocity 1000 to 1500 fpm: Conical tap.
c. Velocity 1500 fpm or Higher: 45-degree lateral.

END OF SECTION 233113

SECTION 233300 - AIR DUCT ACCESSORIES

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Backdraft and pressure relief dampers.
2. Barometric relief dampers.
3. Manual volume dampers.

4. Control dampers.
5. Fire dampers.
6. Ceiling radiation dampers.
7. Smoke dampers.
8. Combination fire and smoke dampers.
9. Corridor dampers.
10. Flange connectors.
11. Duct silencers.
12. Turning vanes.
13. Remote damper operators.
14. Duct-mounted access doors.
15. Flexible connectors.
16. Duct security bars.
17. Duct accessory hardware.

B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 233346 "Flexible Ducts" for insulated and non-insulated flexible ducts.
2. Section 233723 "HVAC Gravity Ventilators" for roof-mounted ventilator caps.

Retain one of two subparagraphs below.

3. Section 284621.11 "Addressable Fire-Alarm Systems" for duct-mounted fire and smoke detectors.
4. Section 284621.13 "Conventional Fire-Alarm Systems" for duct-mounted fire and smoke detectors.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for ASHRAE 62.1.>

C. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.

1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:

a. Special fittings.
b. Manual volume damper installations.
c. Control-damper installations.

d. Fire-damper, smoke-damper, combination fire- and smoke-damper, ceiling, and corridor damper installations, including sleeves; and duct-mounted access doors and remote damper operators.

e. Duct security bars.

Retain "Wiring Diagrams" Subparagraph below if equipment includes wiring.

f. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.

Retain "Source quality-control reports" Paragraph below if retaining "Source Quality Control" Paragraph in "Duct Silencers" Article.

B. Source quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fusible Links: Furnish quantity equal to [**10**] <**Insert number**> percent of amount installed.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 ASSEMBLY DESCRIPTION

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

2.2 MATERIALS

A. Galvanized Sheet Steel: Comply with ASTM A653/A653M.

1. Galvanized Coating Designation: [**G60**] [**G90**].
2. Exposed-Surface Finish: Mill phosphatized.

B. Stainless-Steel Sheets: Comply with ASTM A480/A480M, Type 304, and having a [**No. 2**] <**Insert finish designation**> finish for concealed ducts and <**Insert finish designation**> finish for exposed ducts.

C. Aluminum Sheets: Comply with ASTM B209, Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.

D. Extruded Aluminum: Comply with ASTM B221, Alloy 6063, Temper T6.

E. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

F. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.3 BACKDRAFT AND PRESSURE RELIEF DAMPERS

Copy this article and re-edit for each type of backdraft and pressure relief damper.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Description: Gravity balanced.

C. Maximum Air Velocity: [**1000 fpm**] [**1250 fpm**] [**2000 fpm**] [**3000 fpm**] <**Insert value**>.

D. Maximum System Pressure: [**1-inch wg**] [**2-inch wg**] [**3-inch wg**] [**6-inch wg**] <**Insert value**>.

E. Frame: Hat-shaped, [**0.05-inch-thick, galvanized sheet steel**] [**0.094-inch-thick, galvanized sheet steel**] [**0.063-inch-thick extruded aluminum**] [**0.03-inch-thick stainless steel**] [**0.05-inch-thick stainless steel**], with welded corners or mechanically attached[**and mounting flange**].

F. Blades: Multiple single-piece blades, [**center pivoted,**] [**off-center pivoted,**] [**end pivoted,**] maximum 6-inch width, [**0.025-inch-thick, roll-formed aluminum**] [**0.050-inch-thick aluminum sheet**] [**noncombustible, tear-resistant, neoprene-coated fiberglass**] with sealed edges.

G. Blade Action: Parallel.

H. Blade Seals: [**Felt**] [**Vinyl foam**] [**Extruded vinyl, mechanically locked**] [**Neoprene, mechanically locked**].

I. Blade Axles:

1. Material: [**Nonferrous metal**] [**Galvanized steel**] [**Plated steel**] [**Stainless steel**] [**Nonmetallic**] [**Aluminum**].
2. Diameter: [**0.20 inch**] <**Insert value**>.

J. Tie Bars and Brackets: [**Aluminum**] [**Galvanized steel**].

K. Return Spring: Adjustable tension.

L. Bearings: [**Steel ball**] [**or**] [**synthetic pivot bushings**].

M. Accessories:

1. Adjustment device to permit setting for varying differential static pressure.
2. Counterweights and spring-assist kits for vertical airflow installations.
3. Electric actuators.
4. Chain pulls.

Retain one of two "Screen Mounting" subparagraphs below.

5. Screen Mounting: Front mounted in sleeve.
   a. Sleeve Thickness: 20 gauge minimum.
   b. Sleeve Length: 6 inches minimum.
6. Screen Mounting: Rear mounted.
7. Screen Material: [**Galvanized steel**] [**Aluminum**].
8. Screen Type: [**Bird**] [**Insect**].
9. 90-degree stops.

2.4 BAROMETRIC RELIEF DAMPERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Suitable for horizontal or vertical mounting.

C. Maximum Air Velocity: [**1000 fpm**] [**1250 fpm**] [**2000 fpm**] [**2500 fpm**] <**Insert value**>.

D. Maximum System Pressure: [**2-inch wg**] [**3-inch wg**] [**6-inch wg**] [**10-inch wg**] <**Insert value**>.

E. Frame: Hat-shaped, [**0.05-inch-thick, galvanized sheet steel**] [**0.094-inch-thick, galvanized sheet steel**] [**0.063-inch-thick extruded aluminum**] [**0.03-inch-thick stainless steel**] [**0.05-inch-thick stainless steel**], with welded corners or mechanically attached[**and mounting flange**].

F. Blades:

1. Multiple, [**0.025-inch-thick, roll-formed aluminum**] [**0.050-inch-thick aluminum sheet**].
2. Maximum Width: 6 inches.
3. Action: Parallel.
4. Balance: Gravity.
5. [**Eccentrically pivoted**] [**Off-center pivoted**] [**End pivoted**].

G. Blade Seals: [**Vinyl**] [**Neoprene**].

H. Blade Axles: [**Galvanized steel**] [**Nonferrous metal**] [**Plated steel**] [**Stainless steel**] [**Nonmetallic**].

I. Tie Bars and Brackets:

1. Material: [**Aluminum**] [**Galvanized steel**].
2. Rattle free with 90-degree stop.

J. Return Spring: Adjustable tension.

K. Bearings: [**Synthetic**] [**Stainless steel**] [**Bronze**].

L. Accessories:

1. Flange on intake.
2. Adjustment device to permit setting for varying differential static pressures.
3. <**Insert accessories**>.

2.5 MANUAL VOLUME DAMPERS

Show dampers on Drawings. If both standard and low-leakage volume dampers are required, identify each damper type on Drawings.

A. Standard, Steel, Manual Volume Dampers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Standard leakage rating[**, with linkage outside airstream**].
3. Suitable for horizontal or vertical applications.
4. Frames:

   a. Frame: Hat-shaped, [**0.094-inch-thick, galvanized sheet steel**] [**0.05-inch-thick stainless steel**].
   b. Mitered and welded corners.
   c. Flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

    a. Multiple or single blade.
    b. Parallel- or opposed-blade design.
    c. Stiffen damper blades for stability.
    d. [**Galvanized**] [**Stainless**]-steel, 0.064 inch thick.

6. Blade Axles: [**Galvanized steel**] [**Stainless steel**] [**Nonferrous metal**].
7. Bearings:

    a. [**Oil-impregnated bronze**] [**Molded synthetic**] [**Oil-impregnated stainless-steel sleeve**] [**Stainless-steel sleeve**].
    b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Galvanized steel.

Retain "Standard, Aluminum, Manual Volume Dampers" Paragraph below for aluminum ducts. Coordinate with "Installation" Article and Section 233113 "Metal Ducts."

B. Standard, Aluminum, Manual Volume Dampers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Standard leakage rating[**, with linkage outside airstream**].
3. Suitable for horizontal or vertical applications.
4. Frames: Hat-shaped, 0.10-inch-thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:

    a. Multiple or single blade.
    b. Parallel- or opposed-blade design.
    c. Stiffen damper blades for stability.

Retain "Roll-Formed Aluminum Blades" or "Extruded-Aluminum Blades" Subparagraph below.

    d. Roll-Formed Aluminum Blades: 0.10-inch-thick aluminum sheet.
    e. Extruded-Aluminum Blades: 0.050-inch-thick extruded aluminum.

6. Blade Axles: [**Galvanized steel**] [**Stainless steel**] [**Nonferrous metal**].
7. Bearings:

    a. [**Oil-impregnated bronze**] [**Molded synthetic**] [**Stainless-steel sleeve**].
    b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Aluminum.

C. Low-Leakage, Steel, Manual Volume Dampers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Comply with AMCA 500-D testing for damper rating.

Manufacturers having products tested in AMCA-accredited laboratories, with test results verified by AMCA staff, and having obtained the proper license from AMCA, can offer products bearing AMCA's Certified Ratings Seal for air performance or air leakage, or both. Verify availability with manufacturers retained in list above.

3. Low-leakage rating[**, with linkage outside airstream,**] and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
4. Suitable for horizontal or vertical applications.
5. Frames:
   a. [**Hat**] [**U**] [**Angle**] shaped.
   b. [**0.094-inch-thick, galvanized sheet steel**] [**0.05-inch-thick stainless steel**].
   c. Mitered and welded corners.
   d. Flanges for attaching to walls and flangeless frames for installing in ducts.
6. Blades:
   a. Multiple or single blade.
   b. Parallel- or opposed-blade design.
   c. Stiffen damper blades for stability.
   d. [**Galvanized**] [**Stainless**], roll-formed steel, 0.064 inch thick.
7. Blade Axles: [**Galvanized steel**] [**Stainless steel**] [**Nonferrous metal**].
8. Bearings:
   a. [**Oil-impregnated bronze**] [**Molded synthetic**] [**Oil-impregnated stainless-steel sleeve**] [**Stainless-steel sleeve**].
   b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
9. Blade Seals: [**Felt**] [**Vinyl**] [**Neoprene**].
10. Jamb Seals: Cambered [**stainless steel**] [**aluminum**].
11. Tie Bars and Brackets: [**Galvanized steel**] [**Aluminum**].
12. Accessories:
    a. Include locking device to hold single-blade dampers in a fixed position without vibration.

Retain "Low-Leakage, Aluminum, Manual Volume Dampers" Paragraph below for aluminum ducts. Coordinate with "Installation" Article and Section 233113 "Metal Ducts."

D. Low-Leakage, Aluminum, Manual Volume Dampers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Comply with AMCA 500-D testing for damper rating.

Manufacturers having products tested in AMCA-accredited laboratories, with test results verified by AMCA staff, and having obtained the proper license from AMCA, can offer products bearing AMCA's Certified Ratings Seal for air performance or air leakage, or both. Verify availability with manufacturers retained in list above.

3. Low-leakage rating[**, with linkage outside airstream,**] and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.

4. Suitable for horizontal or vertical applications.
5. Frames: [**Hat**] [**U**] [**Angle**]-shaped, 0.10-inch-thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
6. Blades:

    a. Multiple or single blade.
    b. Parallel- or opposed-blade design.

Retain "Roll-Formed Aluminum Blades" or "Extruded-Aluminum Blades" Subparagraph below.

    c. Roll-Formed Aluminum Blades: 0.10-inch-thick aluminum sheet.
    d. Extruded-Aluminum Blades: 0.050-inch-thick extruded aluminum.

7. Blade Axles: [**Galvanized steel**] [**Stainless steel**] [**Nonferrous metal**].
8. Bearings:

    a. [**Oil-impregnated bronze**] [**Molded synthetic**] [**Oil-impregnated stainless-steel sleeve**] [**Stainless-steel sleeve**].
    b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

9. Blade Seals: [**Felt**] [**Vinyl**] [**Neoprene**].
10. Jamb Seals: Cambered [**stainless steel**] [**aluminum**].
11. Tie Bars and Brackets: [**Galvanized steel**] [**Aluminum**].
12. Accessories:

    a. Include locking device to hold single-blade dampers in a fixed position without vibration.

E. Jackshaft:

1. Size: [**0.5-inch**] [**1-inch**] diameter.
2. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
3. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

F. Damper Hardware:

1. Zinc-plated, die-cast core with dial and handle made of 3/32-inch-thick zinc-plated steel, and a 3/4-inch hexagon locking nut.
2. Include center hole to suit damper operating-rod size.
3. Include elevated platform for insulated duct mounting.

2.6 CONTROL DAMPERS

Retain this article if motorized volume-control dampers are not specified in Section 230923.12 "Control Dampers."

If multiple control-damper types are required, copy this article and re-edit for each type; assign each type a drawing designation and indicate each type on Drawings.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Manufacturers having products tested in AMCA-accredited laboratories, with test results verified by AMCA staff, and having obtained the proper license from AMCA, can offer products bearing AMCA's Certified Ratings Seal for air performance or air leakage, or both. Verify availability with manufacturers retained in the list above.

B. Low-leakage rating[**, with linkage outside airstream,**] and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.

C. Frames:

1. [**Hat**] [**U**] [**Angle**] shaped.
2. [**0.094-inch-thick, galvanized sheet steel**] [**0.05-inch-thick stainless steel**].
3. [**Mitered and welded**] [**Interlocking, gusseted**] corners.

D. Blades:

1. Multiple blade with maximum blade width of [**6 inches**] [**8 inches**].

If retaining second option in first subparagraph below, indicate location of each on Drawings.

2. [**Parallel**] [**Parallel- and opposed**] [**Opposed**]-blade design.
3. [**Galvanized-steel**] [**Stainless steel**] [**Aluminum**].
4. [**0.064 inch thick single skin**] [**or**] [**0.0747-inch-thick dual skin**].

Retain one of two "Blade Edging" subparagraphs below.

5. Blade Edging: [**Closed-cell neoprene**] [**PVC**].
6. Blade Edging: Inflatable seal blade edging, or replaceable rubber seals.

E. Blade Axles: 1/2-inch-diameter; [**galvanized steel**] [**stainless steel**] [**nonferrous metal**]; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.

1. Operating Temperature Range: From minus 40 to plus 200 deg F.

F. Bearings:

1. [**Oil-impregnated bronze**] [**Molded synthetic**] [**Oil-impregnated stainless-steel sleeve**] [**Stainless-steel sleeve**].
2. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
3. Thrust bearings at each end of every blade.

2.7 FIRE DAMPERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

If both types of dampers are required in "Type" Paragraph below, indicate location of each on Drawings.

B. Type: [**Static**] [**and**] [**dynamic**]; rated and labeled according to UL 555 by an NRTL.

Retain first paragraph below for dynamic fire dampers.

C. Closing rating in ducts up to [**4-inch wg**] <**Insert value**> static pressure class and minimum [**2000-fpm**] <**Insert value**> velocity.

If both 1-1/2- and 3-hour ratings are required in "Fire Rating" Paragraph below, indicate location of each rating on Drawings.

D. Fire Rating: [**1-1/2**] [**and**] [**3**] hours.

Type 304, stainless-steel dampers are available for corrosive atmospheres.

E. Frame: [**Curtain type with blades inside airstream**] [**Curtain type with blades outside airstream**] [**Multiple-blade type**] [**Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream**]; fabricated with roll-formed galvanized steel; with mitered and interlocking corners; gauge in accordance with UL listing.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel; gauge in accordance with UL listing.

G. Mounting Orientation: Vertical or horizontal as indicated.

H. Blades: Roll-formed, interlocking, galvanized sheet steel; gauge in accordance with UL listing.

Not all manufacturers use blade locks for horizontal units.

I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

Retain one of two "Heat-Responsive Device" paragraphs below. If multiple temperature ratings are required, indicate location of each heat-responsive-device rating on Drawings.

J. Heat-Responsive Device: Replaceable, [**165 deg F**] [**212 deg F**] <**Insert temperature**> rated, fusible links.

K. Heat-Responsive Device: [**Electric**] [**Pneumatic**], [**resettable**] [**replaceable**] link and switch package, factory installed, [**165 deg F**] [**and**] [**212 deg F**] <**Insert temperature**> rated.

2.8 CEILING RADIATION DAMPERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. General Requirements:

1. Labeled according to UL 555C by an NRTL.
2. Comply with construction details for tested floor- and roof-ceiling assemblies as indicated in UL's "Fire Resistance Directory."

C. Frame: Galvanized sheet steel, round or rectangular, style to suit ceiling construction.

D. Blades: Galvanized sheet steel with refractory insulation.

If multiple temperature ratings are required in "Heat-Responsive Device" Paragraph below, indicate location of each heat-responsive-device rating on Drawings.

E. Heat-Responsive Device: Replaceable, [**165 deg F**] [**212 deg F**] <**Insert temperature**> rated, fusible links.

UL has classified many damper designs ranging from 1/2 to 5 hours. Common values are included in "Fire Rating" Paragraph below. Select damper to match specific ceiling system. If multiple ratings are required, indicate location of each heat-responsive-device rating on Drawings.

F. Fire Rating: [**1**] [**2**] [**3**] <**Insert number**> hour(s).

2.9 SMOKE DAMPERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Manufacturers offer additional features for engineered smoke-control system dampers.

B. General Requirements: Label according to UL 555S by an NRTL.

C. Smoke Detector: Integral, factory wired for single-point connection.

D. Frame: Hat-shaped, galvanized sheet steel, with [**welded**] [**interlocking, gusseted**] [**or**] [**mechanically attached**] corners[**and mounting flange**]; gauge in accordance with UL listing.

Vertical blades are available for special applications.

E. Blades: Roll-formed, horizontal, [**interlocking**] [**overlapping**], galvanized sheet steel; gauge in accordance with UL listing.

F. Leakage: [**Class I**] [**Class II**] <**Insert class**>.

G. Rated pressure and velocity to exceed design airflow conditions.

H. Mounting Sleeve: Factory-installed, galvanized sheet steel; length to suit wall or floor application[**with factory-furnished silicone caulking**]; gauge in accordance with UL listing.

I. Damper Motors: [**Modulating**] [**or**] [**two-position**] action.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

J. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.

4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
6. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
7. Electrical Connection: [**115 V, single phase, 60 Hz**] <**Insert values**>.

K. Accessories:

Retain applicable features in subparagraphs below.

1. Auxiliary switches for [**signaling**] [**fan control**] [**or**] [**position indication**].
2. [**Momentary test switch**] [**Test and reset switches**], [**damper**] [**remote**] mounted.

2.10 COMBINATION FIRE AND SMOKE DAMPERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Type: Dynamic; rated and labeled according to UL 555 and UL 555S by an NRTL.

Available combination fire and smoke dampers include automatic-reopening types and types with electrothermal links that require link replacement after activation. Manufacturers offer additional features for engineered smoke-control system dampers.

Retain first paragraph below for dynamic fire dampers.

C. Closing rating in ducts up to [**4-inch wg**] <**Insert value**> static pressure class and minimum [**2000-fpm**] <**Insert value**> velocity.

If both 1-1/2- and 3-hour ratings are required in "Fire-Rating" Paragraph below, indicate location of each rating on Drawings.

D. Fire Rating: [**1-1/2**] [**and**] [**3**] hours.

Type 304, stainless-steel dampers are available for corrosive atmospheres.

E. Frame: Hat-shaped, galvanized sheet steel, with [**welded**] [**interlocking, gusseted**] [**or**] [**mechanically attached**] corners[**and mounting flange**]; gauge in accordance with UL listing.

Retain one of two "Heat-Responsive Device" paragraphs below for either fusible or resettable links.

Retain one of two temperature options in first "Heat-Responsive Device" Paragraph below for temperature-rated links to suit application requirements. Second option is standard.

F. Heat-Responsive Device: [**Resettable**] [**Replaceable**], [**165 deg F**] [**212 deg F**] rated, [**fusible links**] [**fire-closure device**].

G. Heat-Responsive Device: [**Electric**] [**Pneumatic**] resettable [**link**] [**device**] and switch package, factory installed, rated.

H. Smoke Detector: Integral, factory wired for single-point connection.

Vertical blades are available for special applications.

I. Blades: Roll-formed, horizontal, [**interlocking**] [**overlapping**], galvanized sheet steel; gauge in accordance with UL listing.

J. Leakage: [**Class I**] [**Class II**] <**Insert class**>.

K. Rated pressure and velocity to exceed design airflow conditions.

L. Mounting Sleeve: Factory-installed, galvanized sheet steel; length to suit wall or floor application[**with factory-furnished silicone caulking**]; gauge in accordance with UL listing.

M. Master control panel for use in dynamic smoke-management systems.

N. Damper Motors: [**Modulating**] [**or**] [**two-position**] action.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

O. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
6. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
7. Electrical Connection: 115 V, single phase, 60 Hz.

P. Accessories:

Retain applicable features in subparagraphs below.

1. Auxiliary switches for [**signaling**] [**fan control**] [**or**] [**position indication**].

2. [**Momentary test switch**] [**Test and reset switches**], [**damper**] [**remote**] mounted.

2.11 CORRIDOR DAMPERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Available combination fire and smoke dampers include automatic-reopening types and types with electrothermal links that require link replacement after activation. Manufacturers offer additional features for engineered smoke-control system dampers.

B. General Requirements: Label combination fire and smoke dampers according to UL 555 for 1-hour or 1-1/2-hour rating by an NRTL.

Retain one of two "Heat-Responsive Device" paragraphs below for either fusible or resettable links.

Retain one of two options in first "Heat-Responsive Device" Paragraph for temperature-rated links to suit application requirements. Second option is standard.

C. Heat-Responsive Device: Replaceable, [**165 deg F**] [**212 deg F**] rated, fusible links.

D. Heat-Responsive Device: [**Electric**] [**Pneumatic**] resettable [**link**] [**device**] and switch package, factory installed, rated.

E. Frame: Hat-shaped, galvanized sheet steel, with [**welded**] [**interlocking, gusseted**] [**or**] [**mechanically attached**] corners[**and mounting flange**]; gauge in accordance with UL listing.

Vertical blades are available for special applications.

F. Blades: Roll-formed, horizontal, [**interlocking**] [**overlapping**], galvanized sheet steel; gauge in accordance with UL listing.

G. Mounting Sleeve: Factory-installed, galvanized sheet steel; length to suit wall or floor application; gauge in accordance with UL listing.

H. Damper Motors: [**Modulating**] [**or**] [**two-position**] action.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

I. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.

4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
6. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
7. Electrical Connection: 115 V, single phase, 60 Hz.

2.12 FLANGE CONNECTORS

If permitted by authorities having jurisdiction, flange connectors can substitute for slip-and-drive connections for smoke dampers.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Description: [**Add-on**] [**or**] [**roll-formed**], factory-fabricated, slide-on transverse flange connectors, gaskets, and components.

C. Material: Galvanized steel.

D. Gauge and Shape: Match connecting ductwork.

2.13 DUCT SILENCERS

Duct silencers, with testing-verified performance, can attenuate sound better than many duct design features where performance is only approximated. See Evaluations.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. General Requirements:

1. Factory fabricated.
2. Fire-Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials shall have flame-spread index not exceeding 25 and smoke-developed index not exceeding 50 when tested according to ASTM E84.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. Shape:

1. Rectangular straight with splitters or baffles.
2. Round straight with center bodies or pods.
3. Rectangular elbow with splitters or baffles.
4. Round elbow with center bodies or pods.
5. Rectangular transitional with splitters or baffles.

D. Rectangular Silencer Outer Casing: ASTM A653/A653M, [**G90**] [**G60**], galvanized sheet steel, [**0.034 inch**] [**0.040 inch**] thick.

E. Round Silencer Outer Casing: ASTM A653/A653M, [**G90**] [**G60**], galvanized sheet steel.

1. Sheet Metal Thickness for Units up to 24 Inches in Diameter: 0.034 inch thick.
2. Sheet Metal Thickness for Units 26 through 40 Inches in Diameter: 0.040 inch thick.
3. Sheet Metal Thickness for Units 42 through 52 Inches in Diameter: 0.05 inch thick.
4. Sheet Metal Thickness for Units 54 through 60 Inches in Diameter: 0.064 inch thick.

F. Inner Casing and Baffles: ASTM A653/A653M, [**G90**] [**G60**] galvanized sheet metal, 0.034 inch thick, and with 1/8-inch-diameter perforations.

G. Special Construction:

1. Suitable for outdoor use.
2. High transmission loss[**to achieve STC 45**].

H. Connection Sizes: Match connecting ductwork unless otherwise indicated.

I. Principal Sound-Absorbing Mechanism:

1. Controlled impedance membranes and broadly tuned resonators without absorptive media.
2. [**Dissipative**] [**Film-lined**] type with fill material.

   a. Fill Material: [**Inert and vermin-proof fibrous material, packed under not less than 5 percent compression**] [**Inert and vermin-proof fibrous material, packed under not less than 15 percent compression**] [**Moisture-proof nonfibrous material**].
   b. Erosion Barrier: Polymer bag enclosing fill, and heat sealed before assembly.

In "Lining" Subparagraph below, Mylar and Tedlar are brand names of products manufactured by E.I. du Pont de Nemours and Co.

3. Lining: [**None**] [**Mylar**] [**Tedlar**] [**Fiberglas cloth**] <**Insert material**>.

J. Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations. Do not use mechanical fasteners for unit assemblies.

1. Joints: [**Lock formed and sealed**] [**continuously welded**] [**or**] [**flanged connections**].
2. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
3. Reinforcement: Cross or trapeze angles for rigid suspension.

K. Accessories:

If multiple ratings are required in first subparagraph below, indicate location of each rating on Drawings.

1. Integral [**1-1/2**] [**3**]-hour fire damper with access door.[**Access door to be high transmission loss to match silencer.**]
2. Factory-installed end caps to prevent contamination during shipping.

3. Removable splitters.
4. Airflow measuring devices.

L. Source Quality Control: Test according to ASTM E477.

1. Testing [**of mockups**]to be witnessed by [**Architect**] [**Owner**].
2. Record acoustic ratings, including dynamic insertion loss and generated-noise power levels with an airflow of at least 2000-fpm face velocity.
3. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or 6-inch wg static pressure, whichever is greater.

If Project has more than one type or configuration of duct silencer, delete "Capacities and Characteristics" Paragraph below and schedule duct silencers on Drawings.

M. Capacities and Characteristics:

1. Configuration: [**Straight**] [**90-degree elbow**] <**Insert configuration**>.
2. Shape: [**Rectangular**] [**Round**].
3. Attenuation Mechanism: [**Acoustical glass fiber**] [**Acoustical glass fiber with protective film liner**] [**Helmholtz resonator mechanism with no internal media**].
4. Maximum Pressure Drop: [**0.35-inch wg**] <**Insert value**>.
5. Casing:

   a. Attenuation: [**Standard**] [**High transmission loss**].
   b. Outer Material: [**Galvanized steel**] [**Stainless steel**] [**Aluminum**].
   c. Inner Material: [**Galvanized steel**] [**Stainless steel**] [**Aluminum**].

6. Velocity Range: <**Insert fps**> to <**Insert fps**>.
7. End Connection: [**1-inch slip joint**] [**Flange**].
8. Length: <**Insert inches**>.
9. Face Dimension:

   a. Width: <**Insert inches**>.
   b. Height: <**Insert inches**>.

10. Face Velocity: <**Insert fpm**>.
11. Dynamic Insertion Loss: <**Insert dBA**>.
12. Generated Noise: <**Insert dBA**>.
13. Accessories:

   a. Access door.
   b. Birdscreen.

2.14 TURNING VANES

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain "Manufactured Turning Vanes for Metal Ducts" and "Manufactured Turning Vanes for Nonmetal Ducts" paragraphs below for manufactured turning vanes. Delete for turning vanes fabricated by Installer.

B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

1. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.

C. Manufactured Turning Vanes for Nonmetal Ducts: Fabricate curved blades of resin-bonded fiberglass with acrylic polymer coating; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

D. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 4-3, "Vanes and Vane Runners," and 4-4, "Vane Support in Elbows."

Retain one of two "Vane Construction" paragraphs below.

E. Vane Construction: [**Single**] [**Double**] wall.

F. Vane Construction: Single wall for ducts up to [**48 inches**] <**Insert dimension**> wide and double wall for larger dimensions.

2.15 REMOTE DAMPER OPERATORS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Description: Cable system designed for remote manual damper adjustment.

C. Tubing: [**Brass**] [**Copper**] [**Aluminum**].

D. Cable: [**Stainless steel**] [**Steel**].

E. Wall-Box Mounting: [**Recessed**] [**Surface**].

F. Wall-Box Cover-Plate Material: [**Steel**] [**Stainless steel**].

2.16 DUCT-MOUNTED ACCESS DOORS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 7-2, "Duct Access Doors and Panels," and 7-3, "Access Doors - Round Duct."

1. Door:

a. Double wall, rectangular.
b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
c. Vision panel.
d. Hinges and Latches: 1-by-1-inch butt or piano hinge and cam latches.
e. Fabricate doors airtight and suitable for duct pressure class.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:

a. Access Doors Less Than 12 Inches Square: No hinges and two sash locks.
b. Access Doors up to [**18 Inches**] Square: [**Two hinges**] [**Continuous**] and two sash locks.
c. Access Doors up to 24 by 48 Inches: [**Three hinges**] [**Continuous**] and two compression latches[**with outside and inside handles**].
d. Access Doors Larger Than 24 by 48 Inches: [**Four hinges**] [**Continuous**] and two compression latches with outside and inside handles.

C. Pressure Relief Access Door:

1. Door and Frame Material: Galvanized sheet steel.
2. Door: [**Single wall**] [**Double wall with insulation fill**] with metal thickness applicable for duct pressure class.
3. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.

Retain first subparagraph below if pressure is not indicated on Drawings.

4. Factory set at [**3.0- to 8.0-inch wg**] [**10-inch wg**] <**Insert value**>.
5. Doors close when pressures are within set-point range.
6. Hinge: Continuous piano.
7. Latches: Cam.
8. Seal: Neoprene or foam rubber.
9. Insulation Fill: 1-inch-thick, fibrous-glass or polystyrene-foam board.

2.17 DUCT ACCESS PANEL ASSEMBLIES

Retain this article for access panels in fire-rated duct systems, such as exhaust ducts for commercial kitchen hoods.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Labeled according to UL 1978 by an NRTL.

C. Panel and Frame: Minimum thickness [**0.0528-inch carbon**] [**0.0428-inch stainless**] steel.

D. Fasteners: [**Carbon**] [**Stainless**] steel. Panel fasteners shall not penetrate duct wall.

E. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F.

F. Minimum Pressure Rating: 10-inch wg, positive or negative.

2.18 FLEXIBLE CONNECTORS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Materials: Flame-retardant or noncombustible fabrics.

C. Coatings and Adhesives: Comply with UL 181, Class 1.

Coordinate first five paragraphs below with "Installation" Article. Delete "Metal-Edged Connectors" Paragraph if Contractor is allowed to shop fabricate metal-edged connector or if metal-edged connector is not necessary.

D. Metal-Edged Connectors: Factory fabricated with a fabric strip [**3-1/2 inches**] [**5-3/4 inches**] wide attached to two strips of 2-3/4-inch-wide, 0.028-inch-thick, galvanized sheet steel or 0.032-inch-thick aluminum sheets. Provide metal compatible with connected ducts.

Connector fabric in "Indoor System, Flexible Connector Fabric" Paragraph below is not suitable for exposure to sun, weather, or corrosive environments. It is suitable for system temperatures from minus 10 to plus 200 deg F (minus 23 to plus 93 deg C).

E. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 26 oz./sq. yd..
2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F.

Connector fabric in "Outdoor System, Flexible Connector Fabric" Paragraph below is suitable for exposure to sun, weather, and system temperatures from minus 10 to plus 250 deg F (minus 23 to plus 121 deg C).

F. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone.

1. Minimum Weight: 24 oz./sq. yd..
2. Tensile Strength: 530 lbf/inch in the warp and 440 lbf/inch in the filling.
3. Service Temperature: Minus 50 to plus 250 deg F.

Connectors in "High-Temperature System, Flexible Connectors" Paragraph below are suitable for system temperatures from minus 25 to plus 500 deg F (minus 32 to plus 260 deg C).

G. High-Temperature System, Flexible Connectors: Glass fabric coated with silicone rubber.

1. Minimum Weight: 16 oz./sq. yd..
2. Tensile Strength: 285 lbf/inch in the warp and 185 lbf/inch in the filling.
3. Service Temperature: Minus 67 to plus 500 deg F.

Connectors in "High-Corrosive-Environment System, Flexible Connectors" Paragraph below are suitable for systems handling corrosive gases with temperatures from minus 20 to plus 500 deg F (minus 29 to plus 260 deg C).

H. High-Corrosive-Environment System, Flexible Connectors: Glass fabric with chemical-resistant coating.

1. Minimum Weight: 14 oz./sq. yd..
2. Tensile Strength: 450 lbf/inch in the warp and 340 lbf/inch in the filling.
3. Service Temperature: Minus 67 to plus 500 deg F.

Retain "Thrust Limits" Paragraph below for flexible connection at high-pressure fan discharge.

I. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct.

1. Frame: Steel, fabricated for connection to threaded rods and to allow for a maximum of 30 degrees of angular rod misalignment without binding or reducing isolation efficiency.
2. Outdoor Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
7. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch movement at start and stop.

2.19 DUCT SECURITY BARS

Detail duct security bars on Drawings regardless of field or factory fabrication.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Description: [**Field-fabricated**] [**Factory-fabricated and field-installed**] [**Field- or factory-fabricated and field-installed**] duct security bars.

C. Configuration:

1. Frame: [**2 by 1/4 inch flat frame**] [**2-1/2 by 2-1/2 by 1/4 inch angle**] <**Insert values**>.
2. Sleeve: [**0.1345-inch 3.4-mm**] [**3/16-inch**] <**Insert size**>, [**continuously welded**] [**bent**] steel frames with [**1-by-1-by-3/16-inch**] [**1-1/2-by-1-1/2-by-1/8-inch**] <**Insert size**> angle frame [**factory welded to 1 end**] [**furnished loose for field welding on other end**]. To be poured in place or set with concrete block or welded or bolted to wall, one side only. Duct connections on both sides.
3. Horizontal Bars: [**1/2 inch**] [**2 by 1/4 inch**] <**Insert values**>.
4. Vertical Bars: [**1/2 inch**] [**3/4 inch**] [**1 inch**] [**2 by 1/4 inch**] <**Insert value**>.
5. Bar Spacing: [**6 inches**] <**Insert value**>.
6. Mounting: [**Metal deck or roofing**] [**Bolted or welded**] [**Bolted or welded with masonry anchors**] [**Ductwork or other framing**] [**Poured in place or set with concrete block**] [**Welded or bolted to one wall (one side only**] [**Bar extends 6 inches into wall**].

2.20 DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

Compliance with ASHRAE/IES 90.1 restricts the use of backdraft dampers, and requires control dampers for certain applications.

C. Install [**backdraft**] [**control**] dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

To minimize duct noise generated by volume dampers, SMACNA recommends locating dampers at least two duct diameters from fittings and as far away as possible from outlets.

D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.

Coordinate subparagraphs below with Section 233113 "Metal Ducts."

1. Install steel volume dampers in steel ducts.
2. Install aluminum volume dampers in aluminum ducts.

E. Set dampers to fully open position before testing, adjusting, and balancing.

F. Install test holes at fan inlets and outlets and elsewhere as indicated.

G. Install fire[**and smoke**] dampers according to UL listing.

Retain first paragraph below.

H. Install duct security bars. Construct duct security bars from 0.164-inch steel sleeve, continuously welded at all joints and 1/2-inch-diameter steel bars, 6 inches o.c. in each direction in center of sleeve. Weld each bar to steel sleeve and each crossing bar. Weld 2-1/2-by-2-1/2-by-1/4-inch steel angle to 4 sides and both ends of sleeve. Connect duct security bars to ducts with flexible connections. Provide 12-by-12-inch hinged access panel with cam lock in duct in each side of sleeve.

I. Connect ducts to duct silencers [**with flexible duct connectors**] [**rigidly**].

J. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. On both sides of duct coils.
2. Upstream[**and downstream**] from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.

Retain first three subparagraphs below to provide access for duct cleaning.

7. At each change in direction and at maximum 50-foot spacing.
8. Upstream[**and downstream**] from turning vanes.
9. Upstream or downstream from duct silencers.
10. Control devices requiring inspection.
11. Elsewhere as indicated.

K. Install access doors with swing against duct static pressure.

Sizes in "Access Door Sizes" Paragraph below are from one manufacturer's literature. SMACNA lists only three sizes, 12 by 12 inches (300 by 300 mm), 16 by 20 inches (400 by 500 mm), and 24 by 24 inches (600 by 600 mm), but makes no recommendations for applications. Indicate location and type of each access door on Drawings.

L. Access Door Sizes:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.
3. Head and Hand Access: 18 by 10 inches.
4. Head and Shoulders Access: 21 by 14 inches.
5. Body Access: 25 by 14 inches.
6. Body plus Ladder Access: 25 by 17 inches.

Coordinate first paragraph below with Section 230553 "Identification for HVAC Piping and Equipment."

M. Label access doors according to Section 230553 "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

N. Install flexible connectors to connect ducts to equipment.

O. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

P. Install duct test holes where required for testing and balancing purposes.

Retain paragraph below for thrust limits on flexible connections for fans.

Q. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch movement during start and stop of fans.

3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.
5. Operate remote damper operators to verify full range of movement of operator and damper.

END OF SECTION 233300

SECTION 233346 - FLEXIBLE DUCTS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Access Manufacturer-Provided, AIA MasterSpec-Based Sections:

<Double click here for this Section based on specific manufacturer’s products set as Basis-of-Design at ProductMasterSpec.com.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Non-insulated flexible ducts.
2. Insulated flexible ducts.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for ASHRAE 62.1.>
2. <Double click to insert sustainable design text for adhesives and sealants.>
3. <Double click to insert sustainable design text for insulation.>
4. <Double click to insert sustainable design text for LEED 2009 Prerequisite EA2.>

C. Shop Drawings: For flexible ducts.

1. Include plans showing locations and mounting and attachment details.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from installers of the items involved.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 ASSEMBLY DESCRIPTION

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

C. Comply with the Air Diffusion Council's "ADC Flexible Air Duct Test Code FD 72-R1."

D. Comply with ASTM E96/E96M, "Test Methods for Water Vapor Transmission of Materials."

2.2 NON-INSULATED FLEXIBLE DUCTS

UL 181 defines two categories of flexible ducts. Ducts listed according to UL 181 must pass all UL 181 tests. Air connectors listed according to UL 181 must pass most, but not all, UL 181 tests and are limited to lengths of 14 feet (4.3 m) or less.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain one of five "Non-Insulated, Flexible Duct" paragraphs below to require only one type of non-insulated flexible duct. To require more than one type of non-insulated flexible duct, add drawing designation to each type required and indicate location of each on Drawings.

B. Non-Insulated, Flexible Duct: UL 181, Class 1, two-ply vinyl film supported by helically wound, spring-steel wire.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 10 to plus 160 deg F.

C. Non-Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire.

1. Pressure Rating: 4-inch wg positive and 0.5-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 175 deg F.

D. Non-Insulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 210 deg F.

E. Non-Insulated, Flexible Duct: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 210 deg F.

F. Non-Insulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil.

1. Pressure Rating: 8-inch wg positive or negative.
2. Maximum Air Velocity: 5000 fpm.
3. Temperature Range: Minus 100 to plus 435 deg F.

2.3 INSULATED FLEXIBLE DUCTS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain one of five "Insulated, Flexible Duct" paragraphs below to require only one type of insulated flexible duct. To require more than one type of insulated flexible duct, add drawing designation to each type required and indicate location of each on Drawings.

B. Insulated, Flexible Duct: UL 181, Class 1, two-ply vinyl film supported by helically wound, spring-steel wire; fibrous-glass insulation; [**polyethylene**] [**aluminized**] vapor-barrier film.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 10 to plus 160 deg F.
4. Insulation R-Value: [**Comply with ASHRAE/IES 90.1**] [**R4.2**] [**R6**] [**R8**] <**Insert value**>.

C. Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire; fibrous-glass insulation; [**polyethylene**] [**aluminized**] vapor-barrier film.

1. Pressure Rating: 4-inch wg positive and 0.5-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 175 deg F.
4. Insulation R-Value: [**Comply with ASHRAE/IES 90.1**] [**R4.2**] [**R6**] [**R8**] <**Insert value**>.

D. Insulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire; fibrous-glass insulation; [**polyethylene**] [**aluminized**] vapor-barrier film.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 210 deg F.
4. Insulation R-Value: [**Comply with ASHRAE/IES 90.1**] [**R4.2**] [**R6**] [**R8**] <**Insert value**>.

E. Insulated, Flexible Duct: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire; fibrous-glass insulation; [**polyethylene**] [**aluminized**] vapor-barrier film.

1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
2. Maximum Air Velocity: 4000 fpm.
3. Temperature Range: Minus 20 to plus 210 deg F.
4. Insulation R-Value: [**Comply with ASHRAE/IES 90.1**] [**R4.2**] [**R6**] [**R8**] <**Insert value**>.

F. Insulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil; fibrous-glass insulation; [**polyethylene**] [**aluminized**] vapor-barrier film.

1. Pressure Rating: 8-inch wg positive or negative.
2. Maximum Air Velocity: 5000 fpm.
3. Temperature Range: Minus 20 to plus 250 deg F.
4. Insulation R-Value: [**Comply with ASHRAE/IES 90.1**] [**R4.2**] [**R6**] [**R8**] <**Insert value**>.

2.4 FLEXIBLE DUCT CONNECTORS

A. Clamps: [**Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action**] [**Nylon strap**] in sizes 3 through 18 inches, to suit duct size.

B. Non-Clamp Connectors: [**Adhesive**] [**Liquid adhesive plus tape**] [**Adhesive plus sheet metal screws**].

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install flexible ducts according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

For detailed instructions on properly installing flexible ducts, see "Flexible Duct Performance & Installation Standards" (the Green Book) from ADC (www.flexibleduct.org/ADC_Pubs.asp).

B. Install in indoor applications only. Flexible ductwork should not be exposed to UV lighting.

Retain first paragraph below to allow use of flexible duct to connect terminal units to metal duct.

C. Connect terminal units to supply ducts[**directly or**] with maximum [**12-inch**] <**Insert dimension**> lengths of flexible duct. Do not use flexible ducts to change directions.

D. Connect diffusers or light troffer boots to ducts[**directly or**] with maximum [**60-inch**] <**Insert dimension**> lengths of flexible duct clamped or strapped in place.

E. Connect flexible ducts to metal ducts with [**adhesive**] [**liquid adhesive plus tape**] [**draw bands**] [**adhesive plus sheet metal screws**].

F. Install duct test holes where required for testing and balancing purposes.

"Installation" and "Supporting Flexible Ducts" paragraphs below are excerpts from ADC's Green Book.

G. Installation:

1. Install ducts fully extended.
2. Do not bend ducts across sharp corners.
3. Bends of flexible ducting shall not exceed a minimum of one duct diameter.
4. Avoid contact with metal fixtures, water lines, pipes, or conduits.
5. Install flexible ducts in a direct line, without sags, twists, or turns.

H. Supporting Flexible Ducts:

1. Suspend flexible ducts with bands 1-1/2 inches wide or wider and spaced a maximum of 48 inches apart. Maximum centerline sag between supports shall not exceed 1/2 inch per 12 inches.

2. Install extra supports at bends placed approximately one duct diameter from center line of the bend.
3. Ducts may rest on ceiling joists or truss supports. Spacing between supports shall not exceed the maximum spacing per manufacturer's written installation instructions.
4. Vertically installed ducts shall be stabilized by support straps at a maximum of 72 inches o.c.

END OF SECTION 233346

SECTION 233600 - AIR TERMINAL UNITS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Bypass, single-duct air terminal units.
2. Modulating, single-duct air terminal units.
3. Parallel, fan-powered air terminal units.
4. Series, fan-powered air terminal units.
5. Dual-duct air terminal units.
6. Induction air terminal units.
7. Diffuser-type air terminal units.
8. Balancing terminal units.

9. Pressure control terminal units.
10. Critical environment control valve.
11. Underfloor air distribution terminal units.
12. Underfloor air distribution floor induction units.
13. Exhaust single-duct terminal units.
14. Casing liner.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of air terminal unit.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for air terminal units.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for adhesives.>
2. <Double click to insert sustainable design text for ASHRAE 62.1.>

C. Shop Drawings: For air terminal units.

1. Include plans, elevations, sections, and mounting details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

Retain first subparagraph below if equipment includes wiring.

3. Include diagrams for power, signal, and control wiring.
4. Hangers and supports, including methods for duct and building attachment[**, seismic restraints,**] and vibration isolation.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

D. Delegated-Design Submittal:

1. Materials, fabrication, assembly, and spacing of hangers and supports.
2. Include design calculations[**, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation**] for selecting hangers and supports[**and seismic restraints**].

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Ceiling suspension assembly members.
2. Size and location of initial access modules for acoustic tile.
3. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air terminal units to include in emergency, operation, and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

a. Instructions for resetting minimum and maximum air volumes.
b. Instructions for adjusting software set points.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fan-Powered-Unit Filters: Furnish [**one**] <**Insert number**> spare filter(s) for each filter installed.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 SYSTEM DESCRIPTION

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Sustainable design systems require compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with airstream, particulate filtration, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."

C. ASHRAE Compliance: Applicable requirements in ASHRAE/IES 90.1, "Section 6 - Heating, Ventilating, and Air Conditioning."

2.2 BYPASS, SINGLE-DUCT AIR TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Diverting-damper assembly inside unit casing with control components inside a protective metal shroud.

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain "Diverter Assembly" Paragraph below for units with mechanical volume regulators.

D. Diverter Assembly: [**Galvanized-steel gate, with polyethylene linear bearings**] [**Aluminum blade, with nylon-fitted pivot points**].

Retain first paragraph below for multioutlet attenuator section or indicate number of outlets and outlet sizes on Drawings or in a schedule.

E. Multioutlet Attenuator Section: With [**two**] [**three**] [**four**] <**Insert number**> [**6-inch-**] [**8-inch-**] [**10-inch-**] diameter collars, each with locking butterfly balancing damper.

Verify, with air terminal unit manufacturer, availability of liner.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain one of first two paragraphs below if heating coil is required.

F. Hydronic Heating Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Provide hydronic heating coils for air terminal units scheduled on Drawings.

G. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware. Provide electric-resistance heating coils for air terminal units scheduled on Drawings.

Retain one of first two subparagraphs below.

1. Stage(s): [**1**] [**2**] [**3**].
2. SCR controlled.
3. Access door interlocked disconnect switch.
4. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable).

Subparagraphs below are optional features.

5. Nickel chrome 80/20 heating elements.
6. Airflow switch for proof of airflow.
7. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
8. Mercury contactors.
9. Pneumatic-electric switches and relays.
10. Magnetic contactor for each step of control (for three-phase coils).

Retain one of two paragraphs below, or delete both if controls are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

H. Electric Controls: Damper actuator and thermostat.

1. Damper Actuator: 24 V, powered closed, powered open[**with microswitch to energize heating control circuit**].
2. Thermostat: Wall-mounted electric type with temperature display in Fahrenheit and Celsius, and space temperature set point.

Retain "Changeover Thermostat" Subparagraph below for heating-cooling changeover for morning warm-up.

3. Changeover Thermostat: Duct-mounted, field-adjustable, electric type reverses action of zone thermostat when air temperature reaches 70 deg F.

I. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat. Control devices shall be compatible with temperature controls specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and shall have the following features:

1. Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Thermostat: Wall-mounted electronic type with the following features:

Subparagraphs below are optional features.

a. Temperature set-point display in Fahrenheit and Celsius.
b. Auxiliary switch to energize heating control circuit.
c. Changeover thermistor to reverse action.

Retain "Direct Digital Controls" Paragraph below if control components are specified with control system; delete if control components are packaged with equipment.

J. Direct Digital Controls: Single-package unitary controller and actuator specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

2.3 MODULATING, SINGLE-DUCT AIR TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.
2. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections[**, size matching inlet size**].
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain "Regulator Assembly" Paragraph below for units with system-air-powered volume regulators.

D. Regulator Assembly: System-air-powered bellows section incorporating polypropylene bellows for volume regulation and thermostatic control. Bellows shall operate at temperatures from zero to 140 deg F, shall be impervious to moisture and fungus, shall be suitable for 10-inch wg static pressure, and shall be factory tested for leaks.

E. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

Leakage rates in "Maximum Damper Leakage" Subparagraph below vary among manufacturers and with pressure rating.

1. Maximum Damper Leakage: AHRI 880 rated, [**2**] [**3**] percent of nominal airflow at [**3-inch wg**] [**6-inch wg**] inlet static pressure.
2. Damper Position: Normally [**open**] [**closed**].

F. Attenuator Section: [**0.034-inch steel**] [**0.032-inch aluminum**] sheet.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain first paragraph below for multioutlet attenuator section or indicate number of outlets and outlet sizes on Drawings or in a schedule.

G. Multioutlet Attenuator Section: With [**two**] [**three**] [**four**] <**Insert number**> [**6-inch-**] [**8-inch-**] [**10-inch-**] diameter collars, each with locking butterfly balancing damper.

Retain one of first two paragraphs below if heating coil is required.

H. Hydronic Heating Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Provide hydronic heating coils for air terminal units scheduled on Drawings.

I. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware. Provide electric-resistance heating coils for air terminal units scheduled on Drawings.

Retain one of first two subparagraphs below.

1. Stage(s): [**1**] [**2**] [**3**].
2. SCR controlled.
3. Access door interlocked disconnect switch.
4. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable).

Retain applicable subparagraphs below.

5. Nickel chrome 80/20 heating elements.
6. Airflow switch for proof of airflow.
7. Fan interlock contacts.
8. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
9. Mercury contactors.
10. Pneumatic-electric switches and relays.
11. Magnetic contactor for each step of control (for three-phase coils).

Retain first paragraph below if controls are not specified as a part of the HVAC control system.

J. Control devices shall be compatible with temperature controls system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

1. Electric Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Pneumatic Damper Operator: [**0- to 13-psig**] <**Insert range**> spring range.
3. Electronic Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
4. Electric Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.

If retaining both direct- and reverse-acting thermostats, indicate location of each type on Drawings.

5. Pneumatic Thermostat: Wall-mounted, pneumatic type, [**direct acting**] [**and**] [**reverse acting**] with appropriate mounting hardware.
6. Electronic Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.
7. Pneumatic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
8. Electronic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
9. Terminal Unit Controller: Pressure-independent, variable-air-volume (VAV) controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:

Subparagraphs below are optional features.

   a. Occupied and unoccupied operating mode.
   b. Remote reset of airflow or temperature set points.
   c. Adjusting and monitoring with portable terminal.
   d. Communication with temperature-control system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

10. Room Sensor: Wall mounted with temperature set-point adjustment and access for connection of portable operator terminal.

Retain "Controls" Paragraph below for units with system-powered controls and if control sequences are not specified in Section 230993.11 "Sequence of Operations for HVAC DDC."

K. Controls:

1. Suitable for operation with duct pressures between 0.25- and 3.0-inch wg inlet static pressure.
2. System-powered, wall-mounted thermostat.

L. Control Sequences:

1. Occupied:

   a. On a call for cooling, airflow will increase as the damper opens towards maximum setting to satisfy set point.
   b. On a call for less cooling, airflow will decrease as the damper closes towards minimum setting to satisfy set point.

Retain first subparagraph below if air terminal units have heating coils as indicated in "Hydronic Heating Coils" or "Electric-Resistance Heating Coils" Paragraph, and if control sequences are not specified in Section 230993.11 "Sequence of Operation for HVAC DDC."

c. On a call for heating, after terminal unit has reached minimum airflow set point, [**hydronic heating coil valve will modulate toward open**] [**electric-resistance heating coil will sequence control**] to satisfy set point.

2. Unoccupied:

a. Damper closes to minimum setting.

2.4 PARALLEL FAN-POWERED AIR TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Volume-damper assembly and fan in parallel arrangement inside unit casing with control components inside a protective metal shroud. [**Designed for quiet operation.**] [**Low-profile design.**]

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.
2. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
5. Fan: Forward-curved centrifugal, located at plenum air inlet.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.

Leakage rates in "Maximum Damper Leakage" Subparagraph below vary among manufacturers and with pressure rating.

1. Maximum Damper Leakage: AHRI 880 rated, [**2**] [**3**] percent of nominal airflow at [**3-inch wg**] [**6-inch wg**] inlet static pressure.

"Damper Position" Subparagraph below applies to pneumatic controls only.

2. Damper Position: Normally [**open**] [**closed**].

E. Velocity Sensors: Multipoint array with velocity sensors.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

F. Motor:

1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Type: [**Permanent-split capacitor with SCR for speed adjustment**] [**Electronically commutated motor**].
3. Fan-Motor Assembly Isolation: Rubber isolators.

Verify enclosure types with manufacturer of specified equipment. Delete "Enclosure" Subparagraph below if included in schedule on Drawings.

4. Enclosure: [**Open dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].

Retain first six subparagraphs below if options are available from equipment manufacturers and are different from default requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment." Consider each subparagraph and retain only those that vary from default requirements.

5. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
6. Motor Bearings: <**Insert requirements**>.
7. Unusual Service Conditions:

   a. Ambient Temperature: <**Insert deg F**>.
   b. Altitude: <**Insert feet**> above sea level.

Retain first subparagraph below if application requires this rating.

   c. High humidity.
   d. <**Insert conditions**>.

8. Efficiency: Premium efficient.
9. NEMA Design: <**Insert designation**>.
10. Service Factor: <**Insert value**>.
11. Motor Speed: [**Single speed**] [**Multispeed**].

    a. Speed Control: Infinitely adjustable with pneumatic-electric and electronic controls.

Retain "Electrical Characteristics" Subparagraph below if characteristics are not indicated on Drawings.

12. Electrical Characteristics:

    a. Horsepower: <**Insert horsepower**>.
    b. Volts: [**120**] [**208**] [**230**] [**460**] <**Insert value**>.
    c. Phase: [**Single**] [**Poly**].
    d. Hertz: 60.
    e. Full-Load Amperes: <**Insert value**>.
    f. Minimum Circuit Ampacity: <**Insert value**>.
    g. Maximum Overcurrent Protection: <**Insert amperage**>.

Verify available filter types with manufacturer. Indicate filter thickness in an Air Terminal Unit Schedule on Drawings.

G. Filters:

Retain "Minimum Efficiency Reporting Value and Average Arrestance" Subparagraph below if requiring MERV 1, 2, 3, or 4 in the "Material" subparagraphs below. Retain "Minimum Efficiency Reporting Value" Subparagraph if requiring MERV 5 and higher in "Material" subparagraphs below.

1. Minimum Efficiency Reporting Value and Average Arrestance: According to ASHRAE 52.2.
2. Minimum Efficiency Reporting Value: According to ASHRAE 52.2.

Retain one or more of three "Material" subparagraphs below. Indicate filter type in an Air Terminal Unit Schedule on Drawings if all units are not filtered identically. Two-inch- (50-mm-) thick foam is unavailable. LEED 2009 IEQ Prerequisite 1 and LEED v4 EQ Prerequisite, "Minimum Indoor Air Quality Performance," require compliance with ASHRAE 62.1 (2007 and 2010 versions respectively), which requires a MERV rating of 6 or higher for service to occupied spaces. LEED 2009 IEQ Credit 5 and LEED v4 IEQ Credit, "Enhanced Indoor Air Quality Strategies," require MERV 13 or higher. Insert values appropriate to Project sustainability goals.

3. Material: Polyurethane foam, [**MERV 3**] <**Insert value**> .
4. Material: Glass fiber treated with adhesive, [**MERV 5**] <**Insert value**>.
5. Material: Pleated cotton-polyester media, [**MERV 7**] <**Insert value**>.
6. Thickness: [**2 inches**] [**1 inch**] <**Insert thickness**>.

H. Attenuator Section: [**0.034-inch galvanized steel**] [**0.032-inch aluminum**] sheet.

Verify, with air terminal unit manufacturer, availability of liner.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain one of first two paragraphs below if heating coil is required.

I. Hydronic Heating Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Provide hydronic heating coils for air terminal units scheduled on Drawings.

1. Location: Plenum air inlet.

J. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware. Provide electric-resistance heating coils for air terminal units scheduled on Drawings.

1. Location: Plenum air inlet.

Retain one of first two subparagraphs below.

2. Stage(s): [**1**] [**2**] [**3**].
3. SCR controlled.
4. Access door interlocked disconnect switch.
5. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable).

Retain applicable subparagraphs below.

6. Nickel chrome 80/20 heating elements.
7. Airflow switch for proof of airflow.
8. Fan interlock contacts.
9. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
10. Mercury contactors.
11. Pneumatic-electric switches and relays.
12. Magnetic contactor for each step of control (for three-phase coils).

K. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

1. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
2. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
3. Disconnect Switch: Factory-mounted, fuse type.

L. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.

Retain first paragraph below if controls are not specified as a part of the HVAC control system.

M. Control devices shall be compatible with temperature controls system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

1. Electric Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Pneumatic Damper Operator: [**0- to 13-psig**] <**Insert range**> spring range.
3. Electronic Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
4. Electric Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.
5. Pneumatic Thermostat: Wall-mounted pneumatic type [**direct acting**] [**reverse acting**] [**direct or reverse acting as indicated on Drawings**] with appropriate mounting hardware.
6. Electronic Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.
7. Pneumatic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
8. Electronic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5

percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.

9. Terminal Unit Controller: Pressure-independent, VAV controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:

Retain "Control Sequence" Paragraph below if control sequences are not specified in Section 230993.11 "Sequence of Operations for HVAC DDC."

N. Control Sequence:

1. Occupied (Primary Airflow On):

a. Operate as throttling control for cooling.
b. As cooling requirement decreases, control valve throttles toward minimum airflow.

Retain first option in subparagraph below for electric heat; second option, for hot water.

c. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**][**and electric heat modulates under SCR control**][**and the hot-water coil valve is energized**].

2. Unoccupied (Primary Airflow Off):

a. When pressure at primary inlet is zero or less, fan is de-energized.

Retain first option in subparagraph below for electric heat; second option, for hot water.

b. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**][**and electric heat modulates under SCR control**][**and the hot-water coil valve will be energized**].

2.5 SERIES FAN-POWERED AIR TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

If retaining both options in "Configuration" Paragraph below, indicate location of each configuration on Drawings or in schedule on Drawings.

B. Configuration: Volume-damper assembly and fan in series arrangement inside unit casing with control components inside a protective metal shroud [**for installation above a ceiling**] [**and**] [**within a raised access floor**].

Two subparagraphs below are optional features.

1. Designed for quiet operation.
2. Low-profile design.

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.
2. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
5. Fan: Forward-curved centrifugal.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.

Leakage rates in "Maximum Damper Leakage" Subparagraph below vary among manufacturers and with pressure rating.

1. Maximum Damper Leakage: AHRI 880 rated, [**2**] [**3**] percent of nominal airflow at [**3-inch wg**] [**6-inch wg**] inlet static pressure.

"Damper Position" Subparagraph below applies to pneumatic controls only.

2. Damper Position: Normally [**open**] [**closed**].

E. Velocity Sensors: Multipoint array with velocity sensors in air inlets and air outlets.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

F. Motor:

1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Type: [**Permanent-split capacitor with SCR for speed adjustment**] [**Electronically commutated motor**].
3. Fan-Motor Assembly Isolation: Rubber isolators.

Verify enclosure types with manufacturer of specified equipment. Delete "Enclosure" Subparagraph below if included in schedule on Drawings.

4. Enclosure: [**Open dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].

Retain first six subparagraphs below if options are available from equipment manufacturers and are different from default requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment." Consider each subparagraph and retain only those that vary from default requirements.

5. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
6. Motor Bearings: <**Insert requirements**>.
7. Unusual Service Conditions:

a. Ambient Temperature: <**Insert deg F**>.
b. Altitude: <**Insert feet**> above sea level.

Retain first subparagraph below if application requires this rating.

c. High humidity.
d. <**Insert conditions**>.

8. Efficiency: Premium efficient.
9. NEMA Design: <**Insert designation**>.
10. Service Factor: <**Insert value**>.
11. Motor Speed: [**Single speed**] [**Multispeed**].

a. Speed Control: Infinitely adjustable with pneumatic-electric and electronic controls.

Retain "Electrical Characteristics" Subparagraph below if characteristics are not indicated on Drawings.

12. Electrical Characteristics:

a. Horsepower: <**Insert horsepower**>.
b. Volts: [**120**] [**208**] [**230**] [**460**] <**Insert value**>.
c. Phase: [**Single**] [**Poly**].
d. Hertz: 60.
e. Full-Load Amperes: <**Insert value**>.
f. Minimum Circuit Ampacity: <**Insert value**>.
g. Maximum Overcurrent Protection: <**Insert amperage**>.

Verify available filter types with manufacturer. Indicate filter thickness in an Air Terminal Unit Schedule on Drawings.

G. Filters:

Retain "Minimum Efficiency Reporting Value and Average Arrestance" Subparagraph below if requiring MERV 1, 2, 3, or 4 in "Material" subparagraphs below. Retain "Minimum Efficiency Reporting Value" Subparagraph if requiring MERV 5 and higher in "Material" subparagraphs below.

1. Minimum Efficiency Reporting Value and Average Arrestance: According to ASHRAE 52.2.
2. Minimum Efficiency Reporting Value: According to ASHRAE 52.2.

Retain one or more of three "Material" subparagraphs below. Indicate filter type in an Air Terminal Unit Schedule on Drawings if all units are not filtered identically. Two-inch- (50-mm-) thick foam is unavailable. LEED 2009 IEQ Prerequisite 1 and LEED v4 EQ Prerequisite, "Minimum Indoor Air Quality Performance," require compliance with ASHRAE 62.1 (2007 and 2010 versions respectively), which requires a MERV rating of 6 or higher for service to occupied spaces. LEED 2009 IEQ Credit 5 and LEED v4 IEQ Credit, "Enhanced Indoor Air Quality Strategies," require MERV 13 or higher. Insert values appropriate to Project sustainability goals.

3. Material: Polyurethane foam; [**MERV 3**] <**Insert value**>.
4. Material: Glass fiber treated with adhesive; [**MERV 5**] <**Insert value**>.
5. Material: Pleated cotton-polyester media [**MERV 7**] <**Insert value**>.
6. Thickness: [**2 inches**] [**1 inch**].

H. Attenuator Section: [**0.034-inch galvanized steel**] [**0.032-inch aluminum**] sheet.

Verify, with air terminal unit manufacturer, availability of liner.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain one of first two paragraphs below if heating coil is required.

I. Hydronic Heating Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Provide hydronic heating coils for air-terminal units scheduled on Drawings.

J. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware. Provide electric-resistance heating coils for air terminal units scheduled on Drawings.

Retain one of first two subparagraphs below.

1. Stage(s): [**1**] [**2**] [**3**].
2. SCR controlled.
3. Access door interlocked disconnect switch.
4. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable).

Retain applicable subparagraphs below.

5. Nickel chrome 80/20 heating elements.
6. Airflow switch for proof of airflow.
7. Fan interlock contacts.
8. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
9. Mercury contactors.
10. Pneumatic-electric switches and relays.
11. Magnetic contactor for each step of control (for three-phase coils).

K. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

1. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
2. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
3. Disconnect Switch: Factory-mounted, fuse type.

L. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.

Retain first paragraph below if controls are not specified as a part of the HVAC control system.

M. Control devices shall be compatible with temperature controls system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

1. Electric Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Pneumatic Damper Operator: [**0- to 13-psig**] <**Insert range**> spring range.
3. Electronic Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
4. Electric Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.
5. Pneumatic Thermostat: Wall-mounted pneumatic type [**direct acting**] [**reverse acting**] [**direct or reverse acting as indicated on Drawings**] with appropriate mounting hardware.
6. Electronic Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.
7. Pneumatic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
8. Electronic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
9. Terminal Unit Controller: Pressure-independent, VAV controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:

Retain applicable subparagraphs below.

a. Occupied and unoccupied operating mode.
b. Remote reset of airflow or temperature set points.
c. Adjusting and monitoring with portable terminal.
d. Communication with temperature-control system specified in Division 23 Section "Instrumentation and Control for HVAC."

Retain "Control Sequence" Paragraph below if control sequences are not specified in Section 230993.11 "Sequence of Operations for HVAC DDC."

N. Control Sequence:

1. Occupied (Primary Airflow On):

a. Operate as throttling control for cooling.
b. As cooling requirement decreases, control valve throttles toward minimum airflow.

Retain first option in subparagraph below for electric heat; second option, for hot water.

c. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**][**and electric heat modulates under SCR control**][**and the hot-water coil valve is opened**].

2. Unoccupied (Primary Airflow Off):

a. When externally initiated, begin the morning warm-up/cool-down function. Damper drives to the fully open position without regard for the preset maximum.
b. When pressure at primary inlet is zero or less, fan is de-energized.

Retain first option in subparagraph below for electric heat; second option, for hot water.

c. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**][**and electric heat modulates under SCR control**][**and the hot-water coil valve is opened**].

2.6 DUAL-DUCT AIR TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: [**Mixing**] [**and**] [**non-mixing**] with two volume dampers inside unit casing with mixing attenuator section and control components inside a protective metal shroud[**with a third primary air inlet with volume damper**].

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.
2. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

Leakage rates in "Maximum Damper Leakage" Subparagraph below vary among manufacturers and with pressure rating.

1. Maximum Damper Leakage: AHRI 880 rated, 3 percent of nominal airflow at [**3-inch wg**] [**6-inch wg**] inlet static pressure.

"Damper Position" Subparagraph applies to pneumatic controls only.

2. Damper Position: Normally [**open**] [**closed**].

E. Velocity Sensors: Multipoint array with velocity sensors in air inlets and air outlets.

F. Attenuator Section: [**0.034-inch galvanized steel**] [**0.032-inch aluminum**] sheet.

Verify, with air terminal unit manufacturer, availability of liner.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain first paragraph below for multioutlet attenuator section or indicate number of outlets and outlet sizes on Drawings or in a schedule.

G. Multioutlet Attenuator Section: With [**two**] [**three**] [**four**] <**Insert number**> [**6-inch-**] [**8-inch-**] [**10-inch-**] [**12-inch-**] diameter collars, each with locking butterfly balancing damper.

Verify, with air terminal unit manufacturer, availability of liner.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain first paragraph below if controls are not specified as a part of the HVAC control system.

H. Control devices shall be compatible with temperature controls system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

1. Electric Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Pneumatic Damper Operator: [**0- to 13-psig**] <**Insert range**> spring range.
3. Electronic Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
4. Electric Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.
5. Pneumatic Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.
6. Electronic Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.
7. Pneumatic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
8. Electronic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
9. Terminal Unit Controller: Pressure-independent, VAV controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:

I. Control Sequence:

1. [**System**] [**Room thermostat**] modulates VAV damper and dual-duct damper.[**Room sensor reports temperature.**]
2. When Space Temperature Is below Set Point: Close VAV damper, open hot-deck dampers and close cold-deck dampers, then open VAV damper.
3. When Space Temperature Is above Set Point: Close VAV damper, close hot-deck dampers and open cold-deck dampers, then open VAV damper.

Retain one of two subparagraphs below.

4. Occupancy sensor reports occupancy and enables occupied temperature set point.
5. Occupancy sensor switches set point from occupied setting to unoccupied setting.

2.7 INDUCTION AIR TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Volume-damper assembly inside unit casing with mechanical induction damper mounted on casing and control components inside a protective metal shroud.

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.
2. Air Inlet: Round stub connection for duct attachment.
3. Air Outlet: S-slip and drive connections[**, size matching inlet size**].
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
5. Fan: Forward-curved centrifugal.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

Leakage rates in "Maximum Damper Leakage" Subparagraph below vary among manufacturers and with pressure rating.

1. Maximum Damper Leakage: AHRI 880 rated, [**2**] [**3**] percent of nominal airflow at [**3-inch wg**] [**6-inch wg**] inlet static pressure.
2. Damper Position: Normally [**open**] [**closed**].

E. Induction Damper: Galvanized-steel, multiblade assembly with self-lubricating bearings.

Retain one of first two paragraphs below if heating coil is required.

F. Hydronic Heating Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Provide hydronic heating coils for air terminal units scheduled on Drawings.

G. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware. Provide electric-resistance heating coils for air terminal units scheduled on Drawings.

Retain one of first two subparagraphs below.

1. Stage(s): [**1**] [**2**] [**3**].
2. SCR controlled.
3. Access door interlocked disconnect switch.
4. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable).

Retain applicable subparagraphs below.

5. Nickel chrome 80/20 heating elements.
6. Airflow switch for proof of airflow.
7. Fan interlock contacts.
8. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
9. Mercury contactors.
10. Pneumatic-electric switches and relays.
11. Magnetic contactor for each step of control (for three-phase coils).

Retain first paragraph below if controls are not specified as a part of the HVAC control system.

H. Control devices shall be compatible with temperature controls system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

1. Electric Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Pneumatic Damper Operator: [**0- to 13-psig**] <**Insert range**> spring range.
3. Electronic Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
4. Electric Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.
5. Pneumatic Thermostat: Wall-mounted pneumatic type [**direct acting**] [**reverse acting**] [**direct or reverse acting as indicated on Drawings**] with appropriate mounting hardware.
6. Electronic Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.
7. Pneumatic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
8. Electronic Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.

9. Terminal Unit Controller: Pressure-independent, VAV controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:

I. Control Sequence:

1. Damper controlling induced air from ceiling plenum opens or closes in response to decrease or increase in primary to ensure constant discharge airflow.
2. As heating requirement increases, fan energizes to draw in warm plenum air.

Retain one of three subparagraphs below.

a. Electric heat is energized in steps.
b. Electric heat modulates under SCR control.
c. Hot-water coil valve is opened.

2.8 DIFFUSER-TYPE AIR TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Volume-damper, diffuser, controller assembly[**and electric heater**] and wall-mounted thermostat[**with master-slave capability**].

C. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

D. Diffuser: Galvanized steel with white baked-enamel finish.

Retain "Control Sequence" Paragraph below if controls are not specified as a part of the HVAC control system.

E. Control Sequence: Diffusion dampers open and close to regulate airflow into the room in response to room temperature. The dampers are mechanically actuated by internal, factory-set thermal element thermostats[**with limited field adjustment**].

2.9 BALANCING TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Manually operated volume-damper assembly with locking mechanism inside unit casing with multipoint, center-averaging velocity sensors[**for installation above a ceiling**].

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

1. Leakage: Maximum 2 percent of nominal airflow at 3-inch wg static pressure.
2. Air Inlet: Round stub connection for duct attachment.
3. Air Outlet: S-slip and drive connections.

Verify, with air terminal unit manufacturer, availability of casing liner.

4. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

Leakage rates in "Maximum Damper Leakage" Subparagraph below vary among manufacturers and with pressure rating.

1. Maximum Damper Leakage: AHRI 880 rated, [**2**] [**3**] percent of nominal airflow at [**3-inch wg**] [**6-inch wg**] inlet static pressure.

Retain "Direct Digital Controls" Paragraph below if control components are specified with the control system; delete if control components are packaged with the equipment.

E. Direct Digital Controls: Single-package unitary controller and actuator specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

2.10 PRESSURE CONTROL TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Volume damper assembly inside unit casing with control components inside a protective metal shroud.

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.
2. Air Inlet: Round stub connection for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to diverting damper and other parts requiring service, adjustment, or maintenance; with airtight gasket.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain "Diverter Assembly" Paragraph below for units with mechanical volume regulators.

D. Diverter Assembly: [**Galvanized-steel gate, with polyethylene linear bearings**] [**Aluminum blade, with nylon-fitted pivot points**].

Retain first paragraph below for multioutlet attenuator section or indicate number of outlets and outlet sizes on Drawings or in a schedule.

E. Multioutlet Attenuator Section: With [**two**] [**three**] [**four**] <**Insert number**> [**6-inch-**] [**8-inch-**] [**10-inch-**] diameter collars, each with locking butterfly balancing damper.

Verify, with air terminal unit manufacturer, availability of liner.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain one of two paragraphs below, or delete both if controls are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

F. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat. Control devices shall be compatible with temperature controls specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and shall have the following features:

1. Static pressure tap for field installation.
2. Adjustable control module.

Retain "Direct Digital Controls" Paragraph below if control components are specified with the control system; delete if control components are packaged with the equipment.

G. Direct Digital Controls: Single-package unitary controller and actuator specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

H. Control Sequence:

1. Under the control of a static pressure sensor, damper opens or closes to maintain static pressure downstream branch duct.

2.11 CRITICAL ENVIRONMENT CONTROL VALVE

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: [**Volume damper**] [**Venturi valve**] assembly inside an externally insulated unit casing with control components inside a protective metal shroud.

C. Casing:

1. Type 316 stainless steel, 0.0375 inch, with continuously welded seams.
2. [**Aluminum**] [**Heresite-coated aluminum**].
3. Galvanized steel.

Verify, with air terminal unit manufacturer, availability of casing liner.

4. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

D. Sensors: Multipoint, Type 316 stainless steel[**, removable**].

Retain one of first two paragraphs below if heating coil is required.

E. Hydronic Heating Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Provide hydronic heating coils for air terminal units scheduled on Drawings.

F. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware. Provide electric-resistance heating coils for air terminal units scheduled on Drawings.

Retain one of first two subparagraphs below.

1. Stage(s): [**1**] [**2**] [**3**].
2. SCR controlled.
3. Access door interlocked disconnect switch.
4. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable).

G. Control Sequence:

1. Occupied (Primary Airflow On):

a. Operate as throttling control for cooling.
b. As cooling requirement decreases, control valve throttles toward minimum airflow.

Retain first option in subparagraph below for electric heat; second option, for hot water.

c. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**][**and electric heat modulates under SCR control**][**and the hot-water coil valve is opened**].

2. Unoccupied (Primary Airflow Off):

a. When externally initiated, begin the morning warm-up/cool-down function. Damper drives to the fully open position without regard for the preset maximum.
b. When pressure at primary inlet is zero or less, fan is de-energized.

Retain first option in subparagraph below for electric heat; second option, for hot water.

c. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**][**and electric heat modulates under SCR control**][**and the hot-water coil valve is opened**].

2.12 UNDERFLOOR AIR DISTRIBUTION TERMINAL UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Volume-damper assembly and fan in series arrangement inside unit casing with control components inside a protective metal shroud within a raised access floor. Designed for [**pressurized floor cavity supply**] [**and**] [**ducted air supply**].

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall.

1. Integral floor discharge diffusers.
2. Mixing damper.
3. VAV throttling damper.
4. Leveling feet.

Verify, with air terminal unit manufacturer, availability of casing liner.

5. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.
6. Air Outlet: S-slip and drive connections.
7. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
8. Fan: Forward-curved centrifugal [**in double blower configuration**] [**with double blowers as indicated**].

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

9. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.

Leakage rates in "Maximum Damper Leakage" Subparagraph below vary among manufacturers and with pressure rating.

1. Maximum Damper Leakage: AHRI 880 rated, [**2**] [**3**] percent of nominal airflow at [**3-inch wg**] [**6-inch wg**] inlet static pressure.
2. Damper Position: Normally [**open**] [**closed**].

E. Velocity Sensors: Multipoint array with velocity sensors in air inlets and air outlets.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

F. Motor:

1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Type: [**Permanent-split capacitor with SCR for speed adjustment**] [**Electronically commutated motor**].
3. Fan-Motor Assembly Isolation: Rubber isolators.

Verify enclosure types with manufacturer of specified equipment. Delete "Enclosure" Subparagraph below if included in schedule on Drawings.

4. Enclosure: [**Open dripproof**] [**Totally enclosed, fan cooled**] [**Totally enclosed, air over**] [**Open, externally ventilated**] [**Totally enclosed, nonventilated**] [**Severe duty**] [**Explosion proof**] [**Dust-ignition-proof machine**].

Retain first six subparagraphs below if options are available from equipment manufacturers and are different from default requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment." Consider each subparagraph and retain only those that vary from default requirements.

5. Enclosure Materials: [**Cast iron**] [**Cast aluminum**] [**Rolled steel**].
6. Motor Bearings: <**Insert requirements**>.
7. Unusual Service Conditions:

    a. Ambient Temperature: <**Insert deg F**>.
    b. Altitude: <**Insert feet**> above sea level.

Retain first subparagraph below if application requires this rating.

    c. High humidity.
    d. <**Insert conditions**>.

8. Efficiency: Premium efficient.
9. NEMA Design: <**Insert designation**>.
10. Service Factor: <**Insert value**>.
11. Motor Speed: [**Single speed**] [**Multispeed**].

Retain "Electrical Characteristics" Subparagraph below if characteristics are not indicated on Drawings.

12. Electrical Characteristics:

    a. Horsepower: <**Insert horsepower**>.
    b. Volts: [**120**] [**208**] [**230**] [**460**] <**Insert value**>.
    c. Phase: [**Single**] [**Poly**].
    d. Hertz: 60.
    e. Full-Load Amperes: <**Insert value**>.
    f. Minimum Circuit Ampacity: <**Insert value**>.
    g. Maximum Overcurrent Protection: <**Insert amperage**>.

Retain one or more options in "Controller Type" Paragraph below.

G. Controller Type: [**Plenum Pressure Controllers**] [**Individual Diffuser Controller**] [**Terminal Unit Controller**].

H. Accessories:

1. Inlet filter.
2. Disconnect switch.
3. Transformers.
4. Airflow switch.

I. Control Sequence:

1. Occupied (Primary Airflow On):

    a. Operate as throttling control for cooling.
    b. As cooling requirement decreases, control valve throttles toward minimum airflow.

Retain first option in subparagraph below for electric heat; second option, for hot water.

c. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**][**and electric heat modulates under SCR control**][**and the hot-water coil valve is opened**].

2. Unoccupied (Primary Airflow Off):

a. When externally initiated, begin the morning-warm-up/cool-down function. Damper drives to the fully open position without regard for the preset maximum.
b. When pressure at primary inlet is zero or less, fan is de-energized.

Retain first option in subparagraph below for electric heat; second option, for hot water.

c. As heating requirement increases, fan energizes to draw in warm plenum air[**and electric heat is energized in steps**][**and electric heat modulates under SCR control**][**and the hot-water coil valve is opened**].

2.13 UNDERFLOOR AIR DISTRIBUTION FLOOR INDUCTION UNITS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Raised-access floor-mounting units with ducted primary air[**and hydronic coil(s)**]. Air is discharged to space through nozzles. Design includes secondary air induced from served space.

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall. Casing includes removable aluminum linear grille and plenum[**with interior painted black**].

1. Provide air mixing chamber.
2. Provide casing space for control valves and actuators.
3. Casing to have adjustable feet.

D. Hydronic Heating Coils: [**One row**] [**Two rows**] [**As indicated on Drawings**]. Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Provide hydronic heating coils for air terminal units scheduled on Drawings.

1. Coils to be painted black.

2.14 EXHAUST SINGLE-DUCT TERMINAL

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.

C. Casing: [**0.040-inch-**] [**0.034-inch-**] <**Insert dimension**> thick galvanized steel, single wall. Casing includes removable aluminum linear grille and plenum.

1. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
2. Air Outlet: S-slip and drive connections[**, size matching inlet size**].

3. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.

Retain "Airstream Surfaces" Subparagraph below to comply with sustainable design systems.

4. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Retain "Regulator Assembly" Paragraph below for units with system-air-powered volume regulators.

D. Regulator Assembly: System-air-powered bellows section incorporating polypropylene bellows for volume regulation and thermostatic control. Bellows shall operate at temperatures from zero to 140 deg F, shall be impervious to moisture and fungus, shall be suitable for 10-inch wg static pressure, and shall be factory tested for leaks.

E. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

Leakage rates in "Maximum Damper Leakage" Subparagraph below vary among manufacturers and with pressure rating.

1. Maximum Damper Leakage: AHRI 880 rated, [**2**] [**3**] percent of nominal airflow at [**3-inch wg**] [**6-inch wg**] inlet static pressure.
2. Damper Position: Normally [**open**] [**closed**].

F. Attenuator Section: [**0.034-inch galvanized steel**] [**0.032-inch aluminum**] sheet.

Verify, with air terminal unit manufacturer, availability of casing liner.

1. Casing Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain first paragraph below for multioutlet attenuator section or indicate number of outlets and outlet sizes on Drawings or in a schedule.

G. Multioutlet Attenuator Section: With [**two**] [**three**] [**four**] <**Insert number**> [**6-inch-**] [**8-inch-**] [**10-inch-**] diameter collars, each with locking butterfly balancing damper.

Verify, with air terminal unit manufacturer, availability of liner.

1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for [**fibrous-glass**] [**flexible elastomeric**] duct liner.

Retain one of first five paragraphs below, or delete all five if controls are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

H. Electric Controls: Damper actuator and thermostat.

1. Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.

I. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and shall have the following features:

1. Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg; and shall have a multipoint velocity sensor at air inlet.
3. Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.

Retain first "Direct Digital Controls" Paragraph below if control components are specified with the control system; retain second if control components are packaged with the equipment.

J. Direct Digital Controls: Single-package unitary controller and actuator specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

K. Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with temperature controls specified in Section 230923 "Direct Digital Control (DDC) System for HVAC" and shall have the following features:

1. Damper Actuator: 24 V, powered open, [**spring**] [**capacitous**] return.
2. Terminal Unit Controller: Pressure-independent, VAV controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:

Retain applicable subparagraphs below.

   a. Occupied and unoccupied operating mode.
   b. Remote reset of airflow or temperature set points.
   c. Adjusting and monitoring with portable terminal.
   d. Communication with temperature-control system specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

3. Pressure Sensor: Duct mounted with pressure set-point adjustment[**and access for connection of portable operator terminal**].

Retain "Controls" Paragraph below for units with system-powered controls and if control sequences are not specified in Section 230993.11 "Sequence of Operations for HVAC DDC." Revise sequence descriptions to suit Project.

L. Controls:

1. Suitable for operation with duct pressures between 0.25- and 3.0-inch wg inlet static pressure.
2. System-powered, wall-mounted thermostat.

M. Control Sequence:

1. Damper blade opens or closes to maintain differential pressure set point in response to upstream and downstream differential pressure sensors.

2.15 CASING LINER

See Section 230713 "Duct Insulation" for applicable duct insulation and installation requirements for air terminal device application.

Sustainable design systems require that duct insulation R-value comply with ASHRAE/IES 90.1 tables titled "Minimum Duct Insulation R-Value, Cooling and Heating Only Supply Ducts and Return Ducts" and "Minimum Duct Insulation R-Value, Combined Heating and Cooling Supply Ducts and Return Ducts." If using liner alone to suit thermal requirements, verify that material selected is available in thickness needed to provide thermal performance without jeopardizing other requirements.

Retain one of two "Casing Liner" paragraphs below.

A. Casing Liner: Fibrous-glass duct liner, complying with ASTM C1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Minimum Thickness: [**1/2 inch**] [**3/4 inch**] [**1 inch**].

Retain "Maximum Thermal Conductivity" Subparagraph below to require thermal conductivity exceeding the minimum requirements in ASTM C1071. Retaining subparagraph may create a restrictive proprietary specification.

a. Maximum Thermal Conductivity:

Option for thermal conductivity in first two subparagraphs below exceeds the values in ASTM C1071. If retaining, verify availability of performance with duct liner manufacturers.

1) Type I, Flexible: [**0.27 Btu x in./h x sq. ft. x deg F**] <**Insert value**> at 75 deg F mean temperature.
2) Type II, Rigid: [**0.23 Btu x in./h x sq. ft. x deg F**] <**Insert value**> at 75 deg F mean temperature.

Coating in "Antimicrobial Erosion-Resistant Coating" Subparagraph below is an optional feature for duct liner.

2. Antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. [**Solvent**] [**Water**]-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C916.

a. <Double click to insert sustainable design text for adhesive.>
b. <Double click to insert sustainable design text for adhesive.>

Flexible elastomeric duct liner in "Casing Liner" Paragraph below is not suitable for temperatures higher than 220 deg F (104 deg C).

B. Casing Liner: Flexible elastomeric duct liner fabricated of preformed, cellular, closed-cell, sheet materials complying with ASTM C534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

Available thicknesses for flexible elastomeric duct liner are 3/8, 1/2, 3/4, and 1 inch (10, 13, 19, and 25 mm). Indicate thickness on Drawings.

Surface-burning characteristics in "Minimum Thickness" Subparagraph below are available in limited thicknesses. Verify maximum thickness with manufacturers.

1. Minimum Thickness: [**1/2 inch**] [**3/4 inch**].
2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

   a. <Double click to insert sustainable design text for adhesive.>
   b. <Double click to insert sustainable design text for adhesive.>

2.16 SOURCE QUALITY CONTROL

Retain this article for factory-assembled units. Factory tests are an added cost option and may not be available from some manufacturers. Verify requirement with Owner.

A. Factory Tests: Test assembled air terminal units according to AHRI 880.

1. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, [**coil type,**]and AHRI certification seal.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 5, "Hangers and Supports" and with Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

Verify, with structural engineer, attachment selection and spacing in first two paragraphs below.

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 4 inches thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 4 inches thick.

Retain subparagraph below for projects that require seismic restraints.

5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hangers Exposed to View: Threaded rod and angle or channel supports.

D. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.2 SEISMIC-RESTRAINT-DEVICE INSTALLATION

A. Install hangers and braces designed to support the air terminal units and to restrain against seismic forces required by applicable building codes. Comply with [**SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."**] [**ASCE/SEI 7.**] Comply with requirements for seismic-restraint devices in Section 230548 "Vibration and Seismic Controls for HVAC."

B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.

C. Install cables so they do not bend across edges of adjacent equipment or building structure.

D. Install cable restraints on air terminal units that are suspended with vibration isolators.

E. Install seismic-restraint devices using methods approved by [**an evaluation service member of the ICC Evaluation Service**] [**the Office of Statewide Health Planning and Development for the State of California**] [**an agency acceptable to authorities having jurisdiction**].

F. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.

G. Drilling for and Setting Anchors:

1. Identify position of reinforcing steel and other embedded items before drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Install heavy-duty sleeve anchors with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Set anchors to manufacturer's recommended torque, using a torque wrench.
5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.3 TERMINAL UNIT INSTALLATION

A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

B. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.

Delete paragraph below if thermostats are specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

C. Install wall-mounted thermostats.

3.4 PIPING CONNECTIONS

A. Where installing piping adjacent to air terminal unit, allow space for service and maintenance.

B. Hot-Water Piping: Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 Hydronic Piping Specialties," and connect heating coils to supply with shutoff valve, strainer, control valve, and union or flange; and to return with balancing valve and union or flange.

3.5 DUCTWORK CONNECTIONS

A. Comply with requirements in [**Section 233113 "Metal Ducts"**] [**Section 233116 "Nonmetal Ducts"**] for connecting ducts to air terminal units.

Coordinate duct installations and specialty arrangements with Drawings.

B. Make connections to air terminal units with flexible connectors complying with requirements in Section 233300 "Air Duct Accessories."

3.6 ELECTRICAL CONNECTIONS

A. Install field power to each air terminal unit electrical power connection. Coordinate with air terminal unit manufacturer and installers.

B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

D. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

E. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

Retain one of two subparagraphs below. First subparagraph cross-references Section 260553 "Identification for Electrical Systems" and should be retained for consistent electrical identification. Second is an abbreviated version of the product specified in Section 260553 "Identification for Electrical Systems."

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least [**1/2 inch**] <**Insert dimension**> high.

3.7 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.8 IDENTIFICATION

A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for equipment labels and warning signs and labels.

3.9 FIELD QUALITY CONTROL

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

B. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:

1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.

Retain "Leak Test" Subparagraph below for air terminal units with hot-water coils.

2. Leak Test: After installation, fill water coils and test for leaks. Repair leaks and retest until no leaks exist.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

C. Air terminal unit will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

3.10 STARTUP SERVICE

A. [**Engage a factory-authorized service representative to perform**] [**Perform**] startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
3. Verify that controls and control enclosure are accessible.
4. Verify that control connections are complete.
5. Verify that nameplate and identification tag are visible.
6. Verify that controls respond to inputs as specified.
7. <**Insert startup steps if any**>.

3.11 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain air terminal units.

END OF SECTION 233600

SECTION 233713.13 - AIR DIFFUSERS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Round ceiling diffusers.
2. Rectangular and square ceiling diffusers.
3. Perforated diffusers.
4. Louver face diffusers.
5. Linear bar diffusers.
6. Linear slot diffusers.
7. Ceiling-integral continuous slot diffusers.
8. Light troffer diffusers.

9. Round induction underfloor air-distribution diffusers.
10. Linear underfloor air-distribution diffuser plenums.
11. High-capacity drum louver diffusers.
12. High-capacity, modular-core supply grille diffusers.

B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 233300 "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to diffusers.
2. Section 233713.23 "Air Registers and Grilles" for adjustable-bar register and grilles, fixed-face registers and grilles, and linear bar grilles.
3. Section 233713.43 "Security Registers and Grilles" for security registers and security grilles.
4. Section 233716 "Fabric Air-Diffusion Devices" for continuous tubular diffusers.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
2. Diffuser Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable. Retain "Samples for Initial Selection" and "Samples for Verification" paragraphs for two-stage Samples.

B. Samples: For each exposed product and for each color and texture specified. Actual size of smallest diffuser indicated.

C. Samples for Initial Selection: For diffusers with factory-applied color finishes. Actual size of smallest diffuser indicated.

D. Samples for Verification: For diffusers, in manufacturer's standard sizes to verify color selected. Actual size of smallest diffuser indicated.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Ceiling suspension assembly members.
2. Method of attaching hangers to building structure.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
5. Duct access panels.

B. Source quality-control reports.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and Masterworks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

Descriptions of diffusers include required attributes that define air outlets and inlets. Each description must be edited to include a drawing designation. If there is more than one type of outlet or inlet for a particular description, copy the paragraph for each type required and edit each copy to define each required type. Assign each type a different drawing designation.

2.1 ROUND CEILING DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain first paragraph below for variable-air-volume operations.

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material: [**Steel**] [**Aluminum**].

D. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] [**Anodized aluminum**] <**Insert finish**>.

E. Face Style: [**Four**] [**Three**] [**Two**] cone.

F. Mounting: Duct connection.

G. Pattern: [**Fully adjustable**] [**Two-position horizontal**].

H. Dampers: [**Radial opposed blade**] [**Butterfly**] [**Combination damper and grid**].

I. Accessories:

1. Equalizing grid.
2. Plaster ring.
3. Safety chain.

4. Wire guard.
5. Sectorizing baffles.
6. Operating rod extension.

2.2 RECTANGULAR AND SQUARE CEILING DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain first paragraph below for variable-air-volume operations.

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material: [**Steel**] [**Aluminum**].

D. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] [**Anodized aluminum**] <**Insert finish**>.

E. Face Size: [**24 by 24 inches**] [**20 by 20 inches**] [**12 by 12 inches**] <**Insert dimensions**>.

F. Face Style: [**Three cone**] [**Four cone**] [**Plaque**].

G. Mounting: [**Surface**] [**T-bar**] [**Snap in**] [**Spline**] [**Mounting panel**].

H. Pattern: [**Fixed**] [**Two position**] [**Adjustable**].

I. Dampers: [**Radial opposed blade**] [**Butterfly**] [**Combination damper and grid**].

J. Accessories:

1. Equalizing grid.
2. Plaster ring.
3. Safety chain.
4. Wire guard.
5. Sectorizing baffles.
6. Operating rod extension.

2.3 PERFORATED DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain first paragraph below for variable-air-volume operations.

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material: Steel backpan and pattern controllers, with [**steel**] [**aluminum**] face.

D. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] [**Anodized aluminum**] <**Insert finish**>.

E. Face Size: [**12 by 12 inches**] [**24 by 12 inches**] [**36 by 12 inches**] [**48 by 12 inches**] [**16 by 16 inches**] [**20 by 20 inches**] [**24 by 24 inches**] [**36 by 24 inches**] [**48 by 24 inches**] <**Insert dimensions**>.

F. Duct Inlet: [**Round**] [**Square**].

G. Face Style: [**Flush**] [**Drop extended**].

H. Mounting: [**Surface**] [**T-bar**] [**Snap in**] [**Spline**] [**Mounting panel**].

I. Pattern Controller: [**Four louvered deflector patches**] [**Fixed with curved blades at inlet**] [**Adjustable with louvered pattern modules at inlet**] [**None**].

J. Dampers: [**Opposed blade**] [**Radial opposed blade**] [**Butterfly**] [**Combination damper and grid**] [**Combination volume and fire**].

K. Accessories:

1. Equalizing grid.
2. Plaster ring.
3. Safety chain.
4. Wire guard.
5. Sectorizing baffles.
6. Operating rod extension.

2.4 LOUVER FACE DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain first paragraph below for variable-air-volume operations.

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material: [**Steel**] [**Aluminum**].

D. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] [**Anodized aluminum**] <**Insert finish**>.

E. Face Size: <**Insert inches**>.

F. Mounting: [**Surface**] [**Surface with beveled frame**] [**T-bar**] [**Snap in**] [**Spline**] [**Mounting panel**].

G. Pattern: [**One-way**] [**Two-way**] [**Two-way corner**] [**Three-way**] [**Four-way**] [**Adjustable**] <**Insert pattern**> core style.

H. Dampers: [**Radial opposed blade**] [**Butterfly**] [**Combination damper and grid**].

I. Accessories:

1. Square to round neck adaptor.
2. Adjustable pattern vanes.
3. Throw reducing vanes.
4. Equalizing grid.
5. Plaster ring.
6. Safety chain.
7. Wire guard.
8. Sectorizing baffles.
9. Operating rod extension.

2.5 LINEAR BAR DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain first paragraph below for variable-air-volume operations.

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material: [**Steel**] [**Aluminum**] [**Stainless steel**].

D. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] <**Insert finish**>.

Retain one of first five paragraphs below.

E. Narrow Core Spacing Arrangement: 1/8-inch-thick blades spaced 1/4 inch apart; [**zero**] [**15**]-degree deflection.

F. Wide Core Spacing Arrangement: 1/8-inch-thick blades spaced 1/2 inch apart; [**zero**] [**15**]-degree deflection.

G. Wide Core Spacing Arrangement: 3/16-inch-thick blades spaced 1/2 inch apart; [**zero**] [**15**] [**30**]-degree deflection.

H. Pencil-Proof Core Spacing Arrangement: 3/16-inch-thick blades spaced 7/16 inch apart; [**zero**] [**15**] [**30**]-degree deflection.

I. [**One**] [**Two**]-Way Deflection Vanes: Extruded construction [**fixed**] [**adjustable**] louvers with removable core.

J. Frame: [**1-1/4 inches**] [**1 inch**] [**3/4 inch**] [**1/2 inch**] [**3/16 inch**] wide.

Retain first paragraph below if mounting frame is required.

K. Mounting Frame: [**Filter**] <**Insert frame size and style**>.

L. Mounting: [**Countersunk screw**] [**Concealed bracket**] [**Spring clip**].

M. Damper Type: [**Adjustable opposed-blade assembly**] [**Hinged single blade**].

N. Accessories: [**Plaster frame**] [**Directional vanes**] [**Alignment pins**] [**Core clips**] [**Blank-off strips**].

2.6 LINEAR SLOT DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain first paragraph below for variable-air-volume operations.

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material - Shell: [**Steel**] [**Aluminum**], [**insulated**] [**noninsulated**].

D. Material - Pattern Controller and Tees: Aluminum.

E. Finish - Face and Shell: [**Baked enamel, black**] <**Insert finish**>.

F. Finish - Pattern Controller: [**Baked enamel, black**] <**Insert finish**>.

G. Finish - Tees: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] <**Insert finish**>.

H. Slot Width: [**1/2 inch**] [**3/4 inch**] [**1 inch**] [**1-1/2 inches**].

I. Number of Slots: [**One**] [**Two**] [**Three**] [**Four**] <**Insert number**>.

J. Length: [**24 inches**] [**30 inches**] [**36 inches**] [**48 inches**] [**60 inches**].

K. Accessories: [**Plaster frame**] [**T-bar slot**] [**Center notch**] [**T-bar on inlet side**] [**T-bar on both sides**] [**T-bar clip on one side**] [**T-bar clips on both sides**].

2.7 CEILING-INTEGRAL CONTINUOUS DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Slot Width: [**1 inch**] [**1-1/2 inches**] [**2 inches**] [**2-1/2 inches**] [**3 inches**].

Retain "Section Length" Paragraph below unless length is indicated on Drawings.

C. Section Length: [**12 feet**] <**Insert dimension**>.

D. Straight and curved sections as required to accommodate layout.

Mitered tees and corners are upgrade features, which are not always required.

E. Mitered tees and corners.

F. Pattern Controllers: [**24 inches**] <**Insert dimension**> o.c.

G. Material: Aluminum, extruded, heavy wall.

H. Finishes:

1. Exterior: Standard white.
2. Interior: Standard black.

I. Throw: [**Standard**] [**High**].

J. Mounting: [**Ceiling**] [**Sidewall**].

K. Plenum: [**Noninsulated**] [**Insulated**].

L. Other Features:

1. Painted interior.
2. Blank-offs.

2.8 LIGHT TROFFER DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

Retain first paragraph below for variable-air-volume operations.

B. Devices shall be specifically designed for variable-air-volume flows.

C. Material: Steel[**with external insulation**].

D. Finish: [**None**] [**Black enamel on visible surfaces**] <**Insert finish**>.

E. Slot Width: [**1/2 inch**] [**3/4 inch**] [**1 inch**] [**1-1/2 inches**].

F. Number of Sides: [**One**] [**Two**].

G. Length: [**24 inches**] [**36 inches**] [**48 inches**].

H. Pattern: [**Fixed**] [**Adjustable**].

I. Inlet: [**Top**] [**Side**].

J. Inlet Size: [**5 inches**] [**6 inches**] [**8 inches**].

2.9 ROUND INDUCTION UNDERFLOOR AIR-DISTRIBUTION DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Airflow Principle: Swirl-pattern induction.

C. Material: Plastic, high impact, and resistant to cart and foot traffic.

D. Color: [**Gray**] [**Black**].

E. Components:

1. Diffuser core.
2. Flow regulator.
3. Dirt and liquid catch pan.
4. Spacer flange.
5. Gasketed, underfloor compression ring.

2.10 LINEAR UNDERFLOOR AIR-DISTRIBUTION DIFFUSER PLENUMS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Material: Steel.

C. Finish: White baked acrylic.

D. Deflection: [**Zero**] [**15**] degrees.

E. Components:

1. Aluminum diffuser core.
2. Diffuser frame.
3. Plenum, 0.034-inch steel.

2.11 HIGH-CAPACITY DRUM LOUVER DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Airflow Principle: Extended distance for high airflow rates.

C. Material: Aluminum, heavy gage extruded.

D. Finish: White baked acrylic.

E. Border: 1-1/4-inch width with countersunk screw holes.

F. Gasket between drum and border.

G. Body: Drum shaped; adjustable vertically.

H. Blades: Individually adjustable horizontally.

I. Mounting: Surface to [**duct**] [**wall**].

J. Inlet Width: [**6 inches**] [**10 inches**] [**12 inches**] [**15 inches**] <**Insert dimension**>.

K. Inlet Length: [**12 inches**] [**24 inches**] [**36 inches**] [**60 inches**] <**Insert dimension**>.

L. Accessories:

1. Opposed-blade steel damper.
2. Duct-mounting collars with countersunk screw holes.

2.12 HIGH-CAPACITY, MODULAR-CORE SUPPLY GRILLE DIFFUSERS

Copy this article and re-edit for each product.

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Throw: Extended distance for airflow rates.

C. Material: Steel.

D. Grilles per Unit: [**One**] [**Two**] [**Three**] [**Four**].

E. Finish: White baked acrylic.

F. Border: 1-1/2-inch width with countersunk screw holes.

G. Blades:

1. Airfoil, individually adjustable horizontally.
2. Double deflection.
3. Set in modules.

H. Modules: Removable; rotatable.

I. Mounting: Surface.

J. Accessory: Opposed-blade steel damper.

2.13 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate diffusers according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas where diffusers are installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install diffusers level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install diffusers with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

A. After installation, adjust diffusers to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 233713.13

SECTION 233713.23 - REGISTERS AND GRILLES

TIPS:

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This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Adjustable blade face [**registers**] [**and**] [**grilles**].
2. Fixed face [**registers**] [**and**] [**grilles**].
3. Linear bar grilles.

B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 233300 "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to registers and grilles.
2. Section 233713.13 "Air Diffusers" for various types of air diffusers.
3. Section 233713.43 "Security Registers and Grilles" for security registers and security grilles.
4. Section 233716 "Fabric Air-Diffusion Devices" for continuous tubular diffusers.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
2. Register and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable. Retain "Samples for Initial Selection" and "Samples for Verification" paragraphs for two-stage Samples.

B. Samples: For each exposed product and for each color and texture specified. Smallest size register and grille indicated.

C. Samples for Initial Selection: For registers and grilles with factory-applied color finishes. Smallest size register and grille indicated.

D. Samples for Verification: For registers and grilles, in manufacturer's standard sizes to verify color selected. Smallest size register and grille indicated.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Ceiling suspension assembly members.
2. Method of attaching hangers to building structure.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
5. Duct access panels.

B. Source quality-control reports.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and Masterworks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

Descriptions of registers and grilles include required attributes that define air outlets and inlets. Each description must be edited to include a drawing designation. If there is more than one type of air outlet or inlet for a particular description, copy the paragraph for each type required and edit each copy to define each required type. Assign each type a different drawing designation.

As stated in the Evaluations, MasterSpec defines a register as a combination grille and damper assembly. Some manufacturers listed in SpecAgent and Masterworks Paragraph Builder do not make this distinction. Often, they simply supply grilles with and without dampers.

2.1 REGISTERS

Copy first paragraph below and re-edit for each product.

Insert drawing designation. Use these designations on Drawings to identify each product.

A. Adjustable Blade Face Register <**Insert drawing designation**>:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Material: [**Steel**] [**Aluminum**] [**Stainless steel**].
3. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] <**Insert finish**>.
4. Face Blade Arrangement: [**Horizontal**] [**Vertical**] spaced [**3 inches**] [**1-1/2 inches**] [**3/4 inch**] [**1/2 inch**] <**Insert dimension**> apart.
5. Core Construction: [**Integral**] [**Removable**].

Retain first subparagraph below if rear blades are required.

6. Rear-Blade Arrangement: [**Horizontal**] [**Vertical**] spaced [**3/4 inch**] [**1/2 inch**] <**Insert dimension**> apart.
7. Frame: [**1-1/4 inches**] [**1 inch**] <**Insert dimension**> wide.

Retain first subparagraph below if mounting frame is required.

8. Mounting Frame: [**Filter**] <**Insert frame size and style**>.
9. Mounting: [**Countersunk screw**] [**Concealed**] [**Lay in**].
10. Damper Type: [**Multishutter**] [**Adjustable opposed blade**] [**NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F**].
11. Accessories:

    a. [**Front**] [**Rear**]-blade gang operator.
    b. Filter.

Copy paragraph below and re-edit for each product.

Insert drawing designation. Use these designations on Drawings to identify each product.

B. Fixed Face Register <**Insert drawing designation**>:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Material: [**Steel**] [**Aluminum**].
3. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] <**Insert finish**>.

Retain "Face Blade Arrangement" or "Face Arrangement" Subparagraph below.

4. Face Blade Arrangement: [**Horizontal**] [**Vertical**] spaced [**3/4 inch**] [**1/2 inch**] <**Insert dimension**> apart.
5. Face Arrangement: Perforated core.
6. Core Construction: [**Integral**] [**Removable**].
7. Frame: [**1-1/4 inches**] [**1 inch**] <**Insert dimension**> wide.

Retain first subparagraph below if mounting frame is required.

8. Mounting Frame: [**Filter**] <**Insert frame size and style**>.
9. Mounting: [**Countersunk screw**] [**Concealed**] [**Lay in**].
10. Damper Type: [**Multishutter**] [**Adjustable opposed blade**] [**NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F**].
11. Accessory: Filter.

2.2 GRILLES

Copy first paragraph below and re-edit for each product.

Insert drawing designation. Use these designations on Drawings to identify each product.

A. Adjustable Blade Face Grille <**Insert drawing designation**>:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Material: [**Steel**] [**Aluminum**] [**Stainless steel**].
3. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] <**Insert finish**>.
4. Face Blade Arrangement: [**Horizontal**] [**Vertical**] spaced [**3 inches**] [**1-1/2 inches**] [**3/4 inch**] [**1/2 inch**] <**Insert dimension**> apart.
5. Core Construction: [**Integral**] [**Removable**].

Retain first subparagraph below if rear blades are required.

6. Rear-Blade Arrangement: [**Horizontal**] [**Vertical**] spaced [**3/4 inch**] [**1/2 inch**] <**Insert dimension**> apart.
7. Frame: [**1-1/4 inches**] [**1 inch**] <**Insert dimension**> wide.

Retain first subparagraph below if mounting frame is required.

8. Mounting Frame: [**Filter**] <**Insert frame size and style**>.
9. Mounting: [**Countersunk screw**] [**Concealed**] [**Lay in**].
10. Accessories:

    a. [**Front**] [**Rear**]-blade gang operator.

b. Filter.

Copy first paragraph below and re-edit for each product.

Insert drawing designation. Use these designations on Drawings to identify each product.

B. Fixed Face Grille <**Insert drawing designation**>:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Material: [**Steel**] [**Aluminum**].
3. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] <**Insert finish**>.

Retain "Face Blade Arrangement" or "Face Arrangement" Subparagraph below.

4. Face Blade Arrangement: [**Horizontal**] [**Vertical**]; spaced [**3/4 inch**] [**1/2 inch**] <**Insert dimension**> apart.
5. Face Arrangement: Perforated core.
6. Core Construction: [**Integral**] [**Removable**].
7. Frame: [**1-1/4 inches**] [**1 inch**] <**Insert dimension**> wide.

Retain first subparagraph below if mounting frame is required.

8. Mounting Frame: [**Filter**] <**Insert frame size and style**>.
9. Mounting: [**Countersunk screw**] [**Concealed**] [**Lay in**].
10. Accessory: Filter.

Copy paragraph below and re-edit for each product.

Insert drawing designation. Use these designations on Drawings to identify each product.

C. Linear Bar Grilles <**Insert drawing designation**>

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>
2. Material: [**Steel**] [**Aluminum**].
3. Finish: [**Baked enamel, white**] [**Baked enamel, color selected by Architect**] <**Insert finish**>.

Retain "Face Blade Arrangement" or "Face Arrangement" Subparagraph below.

4. Face Blade Arrangement: [**Horizontal**] [**Vertical**]; spaced [**1/2 inch**] <**Insert dimension**> apart.
5. Face Arrangement: Perforated core.
6. Core Construction: [**Integral**] [**Removable**].
7. Distribution plenum.

   a. Internal insulation.
   b. Inlet damper.

8. Frame: [**1-1/4 inches**] [**1 inch**] <**Insert dimension**> wide.

Retain first subparagraph below if mounting frame is required.

9. Mounting Frame: [**Filter**] <**Insert frame size and style**>.
10. Mounting: [**Countersunk screw**] [**Concealed**] [**Lay in**].

11. Damper Type: [**Adjustable opposed blade**] [**NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F**].

2.3 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate registers and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas where registers and grilles are installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install registers and grilles level and plumb.

B. Outlets and Inlets Locations: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install registers and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

A. After installation, adjust registers and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 233713.23

SECTION 236313 - AIR-COOLED REFRIGERANT CONDENSERS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Packaged air-cooled refrigerant condensers.

1.3 ACTION SUBMITTALS

A. Product Data: For each air-cooled refrigerant condenser.

1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
2. Include equipment dimensions, weights and structural loads, required clearances, method of field assembly, components, and location and size of each field connection.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for enhanced refrigerant management.>
2. <Double click to insert sustainable design text for ASHRAE 90.1.>

C. Shop Drawings: For air-cooled refrigerant condensers.

1. Include plans, elevations, sections, and [**mounting**] [**attachment**] details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

D. Delegated-Design Submittal: For air-cooled refrigerant condensers indicated, to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
2. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Plans, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.

Retain "Seismic Qualification Data" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

B. Seismic Qualification Data: For air-cooled refrigerant condensers, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-cooled refrigerant condensers to include in emergency, operation, and maintenance manuals.

1.6 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 033000 "Cast-in-Place Concrete."

B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 077200 "Roof Accessories."

C. Coordinate location of refrigerant piping and electrical rough-ins.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain air-cooled refrigerant condensers from single source from single manufacturer.

2.2 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

B. Fabricate and label refrigeration system according to ASHRAE 15 and ASHRAE 34.

"ASHRAE/IES 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Sustainable design may require minimum efficiency equal to requirements in ASHRAE/IES 90.1. Insert a specific version of the standard if required to satisfy a Project sustainability requirement.

C. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

Retain "Delegated Design" Paragraph below if Contractor is required to assume responsibility for design.

D. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design vibration isolation[**and seismic restraints**], including comprehensive engineering analysis, using performance requirements and design criteria indicated.

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Data" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

E. Seismic Performance: Air-cooled refrigerant condensers shall withstand the effects of earthquake motions determined according to [**ASCE/SEI 7**] <**Insert requirement**>.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: [**1.5**] [**1.0**].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. <**Insert requirements for Component Amplification Factor and Component Response Modification Factor**>.

F. Capacities and Characteristics:

1. Heat-Rejection Capacity: <**Insert MBh**>.
2. Condensing Temperature:

   a. Saturated Discharge Temperature: <**Insert deg F**>.
   b. Saturated Suction Temperature: <**Insert deg F**>.
   c. Subcooling Temperature: <**Insert deg F**>.

3. Ambient-Air Temperature: <**Insert deg F**>.
4. Refrigerant Pipe Connections:

a. Number of Connections: <**Insert number**>.
b. Liquid Pipe Size: <**Insert NPS**>.
c. Suction Pipe Size: <**Insert NPS**>.

5. Coils:

a. Arrangement: <**Insert description**>.
b. Number of Rows: <**Insert number**>.

In "Fin Spacing" Subparagraph below, verify fin spacing with manufacturer. Not all manufacturers offer all fin spacing options listed.

c. Fin Spacing: [**8 fins/inch**] [**10 fins/inch**] [**12 fins/inch**] [**14 fins/inch**] [**16 fins/inch**] <**Insert value**>.
d. Total Face Area: <**Insert sq. ft.** >.

6. Fans:

a. Number of Condenser Fans: <**Insert number**>.
b. Diameter: <**Insert inches**>.
c. [**Constant**] [**Variable**]-speed.
d. RPM: <**Insert number**>.
e. Total Airflow: <**Insert cfm**>.
f. Condenser Fan Motor Size: <**Insert number**> hp.

7. Electrical Characteristics:

a. Kilowatts: <**Insert number**>.
b. Volts: <**Insert number**>.
c. Phase: <**Insert number**>.
d. Hertz: <**Insert number**>.
e. Maximum Circuit Ampacity: <**Insert number**> A.
f. Maximum Instantaneous Current Flow during Startup: <**Insert number**>.
g. Maximum Overcurrent Protection: <**Insert number**> A.

2.3 PACKAGED AIR-COOLED REFRIGERANT CONDENSERS

A. Description: Factory assembled and tested; consisting of casing, condenser coils, condenser fans and motors, and unit controls.

Verify specific refrigerant choices with manufacturers.

B. Refrigerant: [**R-134A**] [**R-404A**] [**R-407C**] [**or**] [**R-410A**] <**Insert type**>.

C. Condenser Coil: Factory tested at 425 psig.

1. Tube: [**1/2-inch-diameter seamless copper.**] [**3/8-inch-diameter seamless copper.**] [**5/8-inch-diameter seamless copper.**]
2. Coil Fin: [**Aluminum**] [**Copper**].

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment.

3. Motors: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

Retain "Enclosure Type" Subparagraph below if enclosure is not open-dripproof type.

a. Enclosure Type: [**Totally enclosed, air-over (TEAO)**] [**Open, drip-proof (ODP)**].
b. Motor Sizes: Minimum size as indicated. If not indicated, large enough, so driven load will not require motor to operate in service factor range above 1.0.

Retain first subparagraph below to require enclosed switches to be supplied with unit.

c. Mount unit-mounted disconnect switches on [**exterior**] [**interior**] of unit.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

d. <**Insert unique motor characteristics**>.

Retain first subparagraph below if corrosion-resistant coating is desired and is specified in Section 230546 "Coatings for HVAC." If retaining below, consult manufacturers to confirm that the coatings included in the referenced Section are available as a factory-applied coating.

4. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating. See Drawings for condensers requiring a corrosion-resistant coating.

Retain "Coating, Coils," "Coating, Fans," and "Coating, Casing" subparagraphs below if corrosion-resistant coating is desired and is specified in "Materials" Article in this Section.

5. Coating, Coils: [**None**] [**Corrosion resistant**].
6. Coating, Fans: [**None**] [**Corrosion resistant**].
7. Coating, Casing: [**None**] [**Corrosion resistant**].
8. Circuit: To match compressors[**with liquid subcooling coil**].

D. Condenser Fans and Drives:

Retain one of first two subparagraphs below to specify fan type.

1. Directly driven propeller fans with [**aluminum or galvanized-steel**] [**galvanized-steel**] fan blades, for [**vertical**] [**horizontal**] air discharge; manufactured with permanently lubricated ball-bearing motors with integral current- and thermal-overload protection.
2. Forward-curved centrifugal fans for [**vertical**] [**horizontal**] air discharge.

a. Fan on steel shaft with self-aligning ball bearings.
b. V-belt drive with minimum of two belts; variable-pitch drive pulley.
c. Motor mounted on adjustable slide base.

Verify available motor types with manufacturer.

3. Fan Motors:

a. Weather-proof motors with rain shield and shaft slinger.

b. [**Totally enclosed air-over (TEAO)**] [**Open-drip proof (ODP)**].

Retain second option in subparagraph below when fans are controlled by variable-frequency drives (VFDs).

c. [**Constant**] [**Variable**] speed.

E. Operating and Safety Controls: Include condenser fan motor thermal and overload cutouts; [**115-V**] [**24-V**] control transformer, if required; magnetic contactors for condenser fan motors and a nonfused factory-mounted and -wired disconnect switch for single external electrical power connection.

In "Fan Cycling Control" Subparagraph below, retain head pressure sensor option for VFD-controlled motors.

1. Fan Cycling Control: [**Head pressure switches**] [**Head pressure sensors**] [**Ambient thermostats**].

F. Casings: [**Galvanized-steel or zinc-coated-steel treated and finished with manufacturer's standard paint coating**] [**Aluminum**] <**Insert material**>, designed for outdoor installation with weather protection for components and controls, and with the following:

1. Removable panels for access to controls, condenser fans, motors, and drives.
2. Coating: [**None**] [**Corrosion resistant**].
3. [**Vinyl-coated**] [**Plated**] steel fan guards.
4. Lifting holes.

Retain one of four options in subparagraph below for leg height; 20 inches (500 mm) is standard. Verify availability with the manufacturer. Not all manufacturers offer removable legs. Removable legs facilitate easier shipping.

5. Removable legs, [**20 inches**] [**30 inches**] [**36 inches**] [**42 inches**] high.

2.4 MATERIALS

A. Steel:

1. ASTM A36/A36M for carbon structural steel.
2. ASTM A568/A568M for steel sheet.

B. Stainless Steel:

1. Manufacturer's standard grade for casing.
2. Manufacturer's standard type, ASTM A240/A240M for bare steel exposed to airstream or moisture.

C. Galvanized Steel: ASTM A653/A653M.

D. Aluminum: ASTM B209.

Retain "Corrosion-Resistant Coating" Paragraph below if retaining corrosion-resistant coating option in any paragraph above. Subparagraph below will allow either a phenolic or an epoxy coating that meets the requirements below. Determine availability with manufacturers.

E. Corrosion-Resistant Coating: Coat with a corrosion-resistant coating capable of withstanding a [**500**] <**Insert time**>-hour salt-spray test according to ASTM B117.

1. Standards:

a. ASTM B117 for salt spray.
b. ASTM D2794 for minimum impact resistance of 100 in-lb.
c. ASTM B3359 for cross hatch adhesion of 5B.

2. Application: [**Immersion**] [**Spray**].
3. Thickness: [**1 mil**] <**Insert value**>.
4. Gloss: Minimum gloss of 60 on a 60 degree meter.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of air-cooled refrigerant condensers.

B. Examine roughing-in for refrigerant piping systems to verify actual locations of piping connections before equipment installation.

C. Examine walls, floors, and roofs for suitable conditions where air-cooled condensers will be installed.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install units level and plumb, firmly anchored in locations indicated; maintain manufacturer's recommended clearances.

B. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

1. Install air-cooled condenser refrigerant condensers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

Retain one of two subparagraphs below. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device type and minimum deflection in supported equipment schedule on Drawings.

2. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

C. Maintain manufacturer's recommended clearances for service and maintenance.

D. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

3.3 PIPING CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

A. Piping installation requirements are specified in Section 232300 "Refrigerant Piping." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

C. Refrigerant Piping: Where indicated on Drawings, connect piping to unit with pressure-relief, service valve, filter-dryer, and moisture indicator on each refrigerant-circuit liquid line.

D. Apply labels to refrigerant lines in accordance with Section 230553, "Identification for HVAC Piping and Equipment."

3.4 ELECTRICAL CONNECTIONS

A. Install field power to each condenser unit electrical power connection.

B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

D. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

E. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

Retain one of two subparagraphs below. First subparagraph cross-references Section 260553 "Identification for Electrical Systems" and should be retained for consistent electrical identification. Second subparagraph is an abbreviated version of the product specified in Section 260553 "Identification for Electrical Systems."

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least [**1/2 inch**] <**Insert dimension**> high.

3.5 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

C. Install nameplate for each control connection, indicating field control panel designation and I/O control designation feeding connection.

3.6 STARTUP SERVICE

A. [**Engage a factory-authorized service representative to perform**] [**Perform**] startup service.

1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:

    a. Inspect for physical damage to unit casing.
    b. Verify that access doors move freely and are weathertight.
    c. Clean units and inspect for construction debris.
    d. Verify that all bolts and screws are tight.
    e. Adjust vibration isolation and flexible connections.
    f. Verify that controls are connected and operational.

Retain first subparagraph below only for units with centrifugal fans.

2. Lubricate bearings on fan motors.
3. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.

Retain first subparagraph below for units with belt-driven condenser fans.

4. Adjust fan belts to proper alignment and tension.
5. Start unit according to manufacturer's written instructions and complete manufacturer's startup checklist.
6. Measure and record airflow and air-temperature rise over coils.
7. Verify proper operation of capacity control device.
8. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

Retain subparagraph below only for units with centrifugal fans.

9. After startup and performance test, lubricate bearings.

3.7 FIELD QUALITY CONTROL

Retain one of first four paragraphs below. Retain first "Testing Agency" Paragraph below if Owner will hire an independent testing agency.

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

Retain "Testing Agency" Paragraph below to require Contractor to hire an independent testing agency.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform tests and inspections" Paragraph below to require Contractor to perform tests and inspection, and retain option to require Contractor to arrange for the assistance of a factory-authorized service agent.

D. Perform tests and inspections[**with the assistance of a factory-authorized service representative**].

Retain test requirements below with any combination of paragraphs above.

E. Tests and Inspections:

1. Perform electrical test and visual and mechanical inspection.
2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Complete manufacturer's starting checklist.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
5. Verify proper airflow over coils.

F. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

G. Air-cooled refrigerant condensers will be considered defective if they do not pass tests and inspections.

H. Prepare test and inspection reports.

3.8 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain air-cooled refrigerant condensers.

END OF SECTION 236313

SECTION 237213 - HEAT WHEEL AIR-TO-AIR ENERGY RECOVERY UNITS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

This Section may include provisions for LEED 2009, LEED v4, ASHRAE 189.1, IgCC, and Green Globes. Note that some sustainable design requirements are either mandatory or optional requirements that may be inserted in the Section Text using the hypertext links. Other requirements that are associated with sustainable design, and may be considered "best practice" or retained even if a sustainable design standard is not a project requirement, are discussed in the Evaluations.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes heat wheels.

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

B. Related Requirements:

1. Section 233119 "HVAC Casings" for customized housings used for air-to-air energy recovery units.
2. Section 237313.19 "Indoor, Custom Air-Handling Units" for custom housings used for air-to-air energy recovery units.
3. Section 237343.19 "Outdoor, Custom Air-Handling Units" for custom housings used for air-to-air energy recovery units.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated capacities, operating characteristics, furnished specialties, and accessories.

B. Sustainable Design Submittals:

"Product Data" Subparagraph below applies to LEED 2009 NC, CI, CS, and LEED for Schools; LEED v4; IgCC; ASHRAE 189.1; and Green Globes.

1. Product data showing compliance with ASHRAE 62.1.

C. Shop Drawings: For air-to-air energy recovery equipment.

1. Include plans, elevations, sections, details, and [**mounting**] [**attachment**] details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor.

D. Delegated-Design Submittal: For air-to-air energy recovery equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Detail fabrication and assembly of air-to-air energy recovery equipment.
2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
3. Design Calculations: Calculate requirements for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Floor plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Mechanical-room layout and relationships between components and adjacent structural and mechanical elements.
2. Support location, type, and weight.
3. Field measurements.

Retain "Seismic Qualification Data" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

B. Seismic Qualification Data: Certificates, for air-to-air energy recovery equipment, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-to-air energy recovery equipment to include in maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Wheel Belts: [**One**] <**Insert number**> set(s) of belts for each heat wheel.

1.7 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.8 WARRANTY

When warranties are required, verify with Owner's counsel that special warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

A. Special Warranty: Manufacturer agrees to repair or replace components of air-to-air energy recovery equipment that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components with manufacturers listed in Part 2 articles.

1. <**Insert components requiring extended warranty**>.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of unit components.

"ASHRAE Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Sustainable design may require compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, the availability of units with components and features that comply with these requirements.

C. ASHRAE Compliance:

1. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
2. Capacity ratings for air-to-air energy recovery equipment shall comply with ASHRAE 84, "Method of Testing Air-to-Air Heat/Energy Exchangers."

"ASHRAE/IES 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Sustainable design may require minimum efficiency equal to requirements in ASHRAE/IES 90.1.

D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

Retain "Delegated Design" Paragraph below if Contractor is required to assume responsibility for design.

E. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design vibration isolation[**and seismic restraints**], including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Data" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

F. Seismic Performance: Air-to-air energy recovery equipment shall withstand the effects of earthquake motions determined according to [**ASCE/SEI 7**] <**Insert requirement**>.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: [**1.5**] [**1.0**].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. <**Insert requirements for Component Amplification Factor and Component Response Modification Factor**>.

2.2 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of air-to-air energy recovery unit, delete this article and schedule air-to-air energy recovery units on Drawings.

A. Exhaust Air:

1. Airflow: <**Insert value**> cfm.
2. Face Velocity: <**Insert value**> fpm.
3. Summer:

    a. Entering-Air Temperature, Dry Bulb: <**Insert value**> deg F.
    b. Entering-Air Temperature, Wet Bulb: <**Insert value**> deg F.
    c. Leaving-Air Temperature, Dry Bulb: <**Insert value**> deg F.
    d. Leaving-Air Temperature, Wet Bulb: <**Insert value**> deg F.

4. Winter:

a. Entering-Air Temperature, Dry Bulb: <**Insert value**> deg F.
b. Entering-Air Temperature, Wet Bulb: <**Insert value**> deg F.
c. Leaving-Air Temperature, Dry Bulb: <**Insert value**> deg F.
d. Leaving-Air Temperature, Wet Bulb: <**Insert value**> deg F.

5. Air Pressure Drop: <**Insert value**> inches wg.

B. Supply Air:

1. Airflow: <**Insert value**> cfm.
2. Face Velocity: <**Insert value**> fpm.
3. Summer:

a. Entering-Air Temperature, Dry Bulb: <**Insert value**> deg F.
b. Entering-Air Temperature, Wet Bulb: <**Insert value**> deg F.
c. Leaving-Air Temperature, Dry Bulb: <**Insert value**> deg F.
d. Leaving-Air Temperature, Wet Bulb: <**Insert value**> deg F.

4. Winter:

a. Entering-Air Temperature, Dry Bulb: <**Insert value**> deg F.
b. Entering-Air Temperature, Wet Bulb: <**Insert value**> deg F.
c. Leaving-Air Temperature, Dry Bulb: <**Insert value**>deg F.
d. Leaving-Air Temperature, Wet Bulb: <**Insert value**> deg F.

5. Air Pressure Drop: <**Insert value**> inches wg.

C. Wheel Drive:

1. Motor Size: <**Insert horsepower**>.
2. Motor Electrical Characteristics:

a. Volts: [**120**] [**208**] [**230**] <**Insert value**> V.
b. Phase: [**Single**] [**Three**].
c. Hertz: 60 Hz.

D. Effectiveness: <**Insert percentage**>.

2.3 MANUFACTURERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain from single source from single manufacturer.

2.4 HEAT WHEELS

A. Casing:

1. Galvanized steel, stainless steel, or aluminum with standard factory finish.

Retain first subparagraph below to include purge.

2. Integral purge section limiting carryover of exhaust air to between [**0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg**] <**Insert value**> differential pressure.
3. Casing seals on periphery of rotor and on duct divider and purge section.
4. Support vertical rotors on grease-lubricated ball bearings having extended grease fittings[**or permanently lubricated bearings**] with an [**L-10**] <**Insert bearing life**> [**400,000 hours**] <**Insert hours**>. Support horizontal rotors on tapered roller bearing.

Retain one of first two "Rotor" paragraphs below. Not all manufacturers offer each combination of materials and coatings. Consult manufacturers.

B. Rotor: Aluminum or polymer segmented wheel strengthened with radial spokes[**, with nontoxic, noncorrosive, silica-gel desiccant coating**].

C. Rotor: Aluminum, metallic, or polymer segmented wheel strengthened with radial spokes impregnated with nonmigrating, water-selective, 3-angstrom, molecular-sieve desiccant coating.

D. Drive: Fractional horsepower motor and gear reducer[**, with speed changed by variable-frequency controller**] and self-adjusting multilink belt around outside of rotor.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

Retain "Controls" Paragraph below to require heat-wheel controls to be an integral part of air-to-air energy recovery equipment. Delete if heat-wheel controls are specified in Section 230923 "Direct-Digital Control System for HVAC."

E. Controls:

Control options vary with manufacturer. Consult manufacturers.

1. Starting relay, factory mounted and wired, and manual motor starter for field wiring.

Retain one of three "Variable-Frequency Controller" subparagraphs below.

2. Variable-Frequency Controller: Factory mounted and wired, permitting input of field-connected 4- to 20-mA or 1- to 10-V control signal.
3. Variable-Frequency Controller with Exhaust-Air Sensor: Factory mounted and wired, with exhaust-air sensor to vary rotor speed and maintain exhaust temperature above freezing.
4. Variable-Frequency Controller with Exhaust- and Outdoor-Air Sensors: Factory mounted and wired, with exhaust- and outdoor-air sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and maintain[**exhaust temperature above freezing and**] air differential temperature above set point. Rotor speed shall increase to maximum when exhaust-air temperature is less than outdoor-air temperature.
5. Pilot-Light Indicator: Display rotor rotation and speed.

6. Speed Settings: Adjustable settings for maximum and minimum rotor speed limits.
7. <**Insert additional control features**>.

2.5 SOURCE QUALITY CONTROL

A. AHRI 1060 Certification: Testing according to AHRI 1060 and listed and labeled by AHRI.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for electrical services to verify actual locations of connections before installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION OF HEAT WHEELS

A. Install heat wheels so supply and exhaust airstreams flow in opposite directions and rotation is away from exhaust side to purge section to supply side.

1. Install access doors in both supply and exhaust ducts, both upstream and downstream, for access to wheel surfaces, drive motor, and seals.
2. Install removable panels or access doors between supply and exhaust ducts on building side for bypass during startup.
3. Access doors and panels are specified in Section 233300 "Air Duct Accessories."

B. Install floor-mounted units on 4-inch-high concrete base[**designed to withstand, without damage to equipment, seismic force required by code**].

C. Equipment Mounting:

Retain subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases without vibration isolation devices.

1. Install air-to-air energy recovery equipment on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

Retain first paragraph below for air-to-air energy recovery equipment requiring seismic restraints.

D. Install seismic restraints according to manufacturers' written instructions.

Retain first paragraph below for suspended units. Retain option for projects in seismic areas.

E. Suspended Units: Suspend[**and brace**] units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

F. Install units with clearances for service and maintenance.

G. Comply with requirements for ductwork specified in Section 233113 "Metal Ducts."

3.3 PIPING CONNECTIONS

Coordinate piping installations and specialty arrangements with Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to unit, allow space for service and maintenance.

C. Connect piping to units mounted on vibration isolators with flexible connectors.

Retain one of two "Condensate Drain Piping" paragraphs below.

D. Condensate Drain Piping: Pipe drains from drain pans to nearest floor drain; use ASTM B88, Type L, drawn-temper copper water tubing with soldered joints, same size as condensate drain connection.

E. Condensate Drain Piping: Pipe drains from drain pans to nearest floor drain; use ASTM D1785, Schedule 40 PVC pipe and solvent-welded fittings, same size as condensate drain connection.

F. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

3.4 ELECTRICAL CONNECTIONS

A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

C. Install electrical devices furnished by manufacturer, but not factory mounted, according to NFPA 70 and NECA 1.

D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

Retain one of two subparagraphs below. First subparagraph cross-references Section 260553 "Identification for Electrical Systems" and should be retained for consistent electrical identification.

Second subparagraph is an abbreviated version of the product specified in Section 260553 "Identification for Electrical Systems."

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.5 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring according to Section 260523 "Control-Voltage Electrical Power Cables."

3.6 FIELD QUALITY CONTROL

Retain one of first four paragraphs below. Retain first "Testing Agency" Paragraph below if Owner will hire an independent testing agency.

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

Retain "Testing Agency" Paragraph below to require Contractor to hire an independent testing agency.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections and retain option to require Contractor to arrange for the assistance of a factory-authorized service agent.

D. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
2. Adjust seals and purge.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
4. Set initial temperature and humidity set points.
5. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

E. Air-to-air energy recovery equipment will be considered defective if it does not pass tests and inspections.

F. Prepare test and inspection reports.

3.7 STARTUP SERVICE

A. [**Engage a factory-authorized service representative to perform**] [**Perform**] startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, wheel rotation, and smooth bearing operations. Reconnect motor drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.

3.8 ADJUSTING

A. Comply with requirements for air-handling system testing, adjusting, and balancing in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.9 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain air-to-air energy recovery units.

END OF SECTION 237213

SECTION 237313.13 - INDOOR, BASIC AIR-HANDLING UNITS

TIPS:

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Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

This Section may include provisions for LEED 2009, LEED v4, ASHRAE 189.1, IgCC, and Green Globes. Note that some sustainable design requirements are either mandatory or optional requirements that may be inserted in the Section Text using the hypertext links. Other requirements that are associated with sustainable design, and may be considered "best practice" or retained even if a sustainable design standard is not a project requirement, are discussed in the Evaluations.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes factory-assembled, indoor air-handling units with limited features, including the following components and accessories:

1. Casings.
2. Fans, drives, and motors.
3. Coils.
4. Air filtration.

5. Dampers.

1.3 ACTION SUBMITTALS

A. Product Data: For each air-handling unit.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
3. Include unit dimensions and weight.
4. Include cabinet material, metal thickness, finishes, insulation, and accessories.
5. Fans:

a. Include certified fan-performance curves with system operating conditions indicated.
b. Include certified fan-sound power ratings.
c. Include fan construction and accessories.
d. Include motor ratings, electrical characteristics, and motor accessories.

6. Include certified coil-performance ratings with system operating conditions indicated.
7. Include filters with performance characteristics.

Retain subparagraph below if items are furnished as parts of air-handling units.

8. Include dampers, including housings, linkages, and operators.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for ASHRAE 62.1.>
2. <Double click to insert sustainable design text for AHU filter performance.>
3. <Double click to insert sustainable design text for adhesives, mastics, and sealants submittals.>

C. Shop Drawings: For each type and configuration of indoor, basic, air-handling unit.

1. Include plans, elevations, sections, and [**mounting**] [**attachment**] details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Detail fabrication and assembly of indoor, basic air-handling units, as well as procedures and diagrams.
4. Include diagrams for power, signal, and control wiring.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor. Professional engineer qualifications below are specified in Section 014000 "Quality Requirements."

D. Delegated-Design Submittal: For vibration isolation[**and seismic restraints**] indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Include design calculations for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Floor plans and other details, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.

Retain "Seismic Qualification Data" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

B. Seismic Qualification Data: Certificates for indoor, basic air-handling units, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
4. Restraint of internal components.

C. Source quality-control reports.

D. Startup service reports.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

E. Field quality-control reports.

F. Sample Warranty: For manufacturer's warranty.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Filters: [**One**] <**Insert number**> set(s) for each air-handling unit.
2. Gaskets: [**One**] <**Insert number**> set(s) for each access door.
3. Fan Belts: [**One**] <**Insert number**> set(s) for each air-handling unit fan.

1.7 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

A. Warranty: Manufacturer agrees to repair or replace components of indoor, basic, air-handling units that fail in materials or workmanship within specified warranty period.

   1. Warranty Period: Manufacturer's standard, but not less than [**one**] <**Insert number**> year(s) from date of Substantial Completion.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.

"ASHRAE 62.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Sustainable design may require compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, the availability of units with components and features that comply with these requirements.

C. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

"ASHRAE/IES 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Sustainable design may require minimum efficiency equal to requirements in ASHRAE/IES 90.1.

D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

Retain "Delegated Design" Paragraph below if Contractor is required to assume responsibility for design.

E. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design vibration isolation[**and seismic restraints**], including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

Not all basic air-handling unit manufacturers publish deflection rates indicated in "Structural Performance" Paragraph below. Retain and revise after consulting manufacturers.

F. Structural Performance: Casing panels shall be self-supporting and capable of withstanding positive/negative [**4-inch wg**] <**Insert value**> of internal static pressure, without exceeding a midpoint deflection of [**0.005 inches/inch**] <**Insert value**> of panel span.

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Data" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

G. Seismic Performance: Air-handling units shall withstand the effects of earthquake motions determined according to [**ASCE/SEI 7**] <**Insert requirement**>.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: [**1.5**] [**1.0**].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. <**Insert requirements for Component Amplification Factor and Component Response Modification Factor**>.

2.2 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of air-handling unit, delete this article and schedule air-handling units on Drawings.

A. Supply Fan:

A few, but not all, manufacturers offer Type SWSI, airfoil unhoused centrifugal fans. Coordinate retained option in "Type" Subparagraph below with manufacturers.

1. Type: [**DWDI, forward-curved centrifugal fan**] [**SWSI, airfoil unhoused centrifugal plenum fan**] <**Insert fan type**>.

Coordinate "Class" designation in first subparagraph below with fan performance requirements and fan class availability of manufacturers.

2. [**Class I**] [**Class II**]: AMCA 99-2408.

For basic air-handling units, most manufacturers offer v-belt drive with forward-curved fans and direct drive with unhoused centrifugal fans. Coordinate retained option in "Drive" Subparagraph below with manufacturers.

3. Drive: [**V-belt**] [**Direct**].

The majority of manufacturers offer one fan; coordinate with manufacturers if indicating more than one.

4. Number of Fan Wheels: [**One**] <**Insert number**>.
5. Fan Diameter: <**Insert number**> inches.
6. Airflow: <**Insert number**> cfm.
7. Total Static Pressure: <**Insert number**> inches wg.
8. External Static Pressure: <**Insert number**> inches wg.
9. Speed: <**Insert rpm**>.
10. Maximum Outlet Velocity: <**Insert number**> fpm.
11. Motor:

    a. Size: <**Insert horsepower**>.
    b. Speed: <**Insert rpm**>.
    c. Volts: [**208**] [**230**] [**460**] <**Insert value**> V.
    d. Phase: [**Three**] <**Insert number**>.
    e. Hertz: [**60**] <**Insert number**> Hz.
    f. Full-Load Amperes: <**Insert value**> A.
    g. Minimum Circuit Ampacity: <**Insert value**> A.
    h. Maximum Overcurrent Protection: <**Insert amperage**> A.

12. Fan Discharge Sound Power, dB:

    a. 1st Octave: <**Insert value**>.
    b. 2nd Octave: <**Insert value**>.
    c. 3rd Octave: <**Insert value**>.
    d. 4th Octave: <**Insert value**>.
    e. 5th Octave: <**Insert value**>.
    f. 6th Octave: <**Insert value**>.
    g. 7th Octave: <**Insert value**>.
    h. 8th Octave: <**Insert value**>.

B. [**Return**]Fan:

1. Type: [**DWDI, forward-curved centrifugal fan**] [**SWSI, airfoil unhoused centrifugal plenum fan**] <**Insert fan type**>.
2. [**Class I**] [**Class II**]: AMCA 99-2408.
3. Drive: [**V-belt**] [**Direct**].

The majority of manufacturers offer one fan; coordinate with manufacturers if indicating more than one.

4. Number of Fan Wheels: [**One**] <**Insert number**>.

5. Fan Diameter: <**Insert number**> inches.
6. Airflow: <**Insert number**> cfm.
7. Total Static Pressure: <**Insert number**> inches wg.
8. External Static Pressure: <**Insert number**> inches wg.
9. Speed: <**Insert rpm**>.
10. Maximum Outlet Velocity: <**Insert number**> fpm.
11. Motor:

    a. Size: <**Insert value**> hp.
    b. Speed: <**Insert rpm**>.
    c. Volts: [**208**] [**230**] <**Insert value**> V.
    d. Phase: [**Three**] <**Insert number**>.
    e. Hertz: [**60**] <**Insert number**> Hz.
    f. Full-Load Amperes: <**Insert value**> A.
    g. Minimum Circuit Ampacity: <**Insert value**> A.
    h. Maximum Overcurrent Protection: <**Insert amperage**> A.

12. Fan Inlet Sound Power, dB:

    a. 1st Octave: <**Insert value**>.
    b. 2nd Octave: <**Insert value**>.
    c. 3rd Octave: <**Insert value**>.
    d. 4th Octave: <**Insert value**>.
    e. 5th Octave: <**Insert value**>.
    f. 6th Octave: <**Insert value**>.
    g. 7th Octave: <**Insert value**>.
    h. 8th Octave: <**Insert value**>.

C. Preheat Coil:

1. Heat-Transfer Rate: <**Insert number**> Btu/h.
2. Entering-Air Temperature: <**Insert number**> deg F.
3. Leaving-Air Temperature: <**Insert number**> deg F.
4. Face Area: <**Insert number**> sq. ft..
5. Maximum Face Velocity: <**Insert number**> fpm.
6. Maximum Air-Side, Static-Pressure Drop: <**Insert number**> inches wg.
7. Fin Spacing: Maximum <**Insert number**> fins per inch.
8. Minimum Number of Rows: <**Insert number**>.
9. Water:

    a. Water Flow: <**Insert number**> gpm.
    b. Maximum Water Pressure Drop: <**Insert number**> feet of head.
    c. Entering-Water Temperature: <**Insert number**> deg F.
    d. Leaving-Water Temperature: <**Insert number**> deg F.
    e. Tube Velocity: <**Insert number**> fpm.

10. Steam:

    a. Steam Flow: <**Insert number**> lb/h.
    b. Inlet Steam Pressure: <**Insert number**> psig.
    c. Outer-Tube Diameter: <**Insert number**> inches.

D. Heating Coil:

1. Heat-Transfer Rate: <**Insert number**> Btu/h.
2. Entering-Air Temperature: <**Insert number**> deg F.
3. Leaving-Air Temperature: <**Insert number**> deg F.
4. Face Area: <**Insert number**> sq. ft..
5. Maximum Face Velocity: <**Insert number**> fpm.
6. Maximum Air-Side, Static-Pressure Drop: <**Insert number**> inches wg.
7. Number of Rows: <**Insert number**>.
8. Fin Spacing: Maximum <**Insert number**> fins per inch.
9. Water:

    a. Water Flow: <**Insert number**> gpm.
    b. Maximum Water Pressure Drop: <**Insert number**> feet of head.
    c. Entering-Water Temperature: <**Insert number**> deg F.
    d. Leaving-Water Temperature: <**Insert number**> deg F.
    e. Tube Velocity: <**Insert number**> fpm.

10. Steam:

    a. Steam Flow: <**Insert number**> lb/h.
    b. Inlet Steam Pressure: <**Insert number**> psig.

E. Electric Heating Coil:

1. Heat-Transfer Rate: <**Insert number**> Btu/h.
2. Input: <**Insert kilowatts**>.
3. Volts: [**120**] [**208**] [**230**] <**Insert value**> V.
4. Phase: [**Single**] [**Three**].
5. Full-Load Amperes: <**Insert value**> A.
6. Number of Steps: <**Insert number**>.

F. Cooling Coil:

1. Sensible Heat-Transfer Rate: <**Insert number**> Btu/h.
2. Total Heat-Transfer Rate: <**Insert number**> Btu/h.
3. Entering-Air, Dry-Bulb Temperature: <**Insert number**> deg F.
4. Entering-Air, Wet-Bulb Temperature: <**Insert number**> deg F.
5. Leaving-Air, Dry-Bulb Temperature: <**Insert number**> deg F.
6. Leaving-Air, Wet-Bulb Temperature: <**Insert number**> deg F.
7. Face Area: <**Insert number**> sq. ft..
8. Maximum Face Velocity: <**Insert number**> fpm.
9. Maximum Air-Side, Static-Pressure Drop: <**Insert number**> inches wg.
10. Number of Rows: <**Insert number**>.
11. Fin Spacing: Maximum <**Insert number**> fins per inch.
12. Water:

    a. Water Flow: <**Insert number**> gpm.
    b. Maximum Water Pressure Drop: <**Insert number**> feet of head.
    c. Entering-Water Temperature: <**Insert number**> deg F.
    d. Leaving-Water Temperature: <**Insert number**> deg F.

e. Tube Velocity: <**Insert number**> fpm.

13. Refrigerant:

a. Refrigerant Type: <**Insert refrigerant type**>.

G. Filters:

1. Type: <**Insert type**>.
2. Face Dimensions, each: <**Insert number**> inches by inches.
3. Depth: <**Insert number**> inches.
4. Number of Filters in Filter Bank: <**Insert number**> wide by <**Insert number**> high.
5. Access Location: [**Side**] <**Insert location**>.
6. Maximum or Rated Face Velocity: <**Insert number**> fpm.
7. Initial Resistance: <**Insert number**> inches wg.
8. Recommended Final Resistance: <**Insert number**> inches wg.

Retain "Minimum Efficiency Reporting Value and Average Arrestance" Subparagraph below if requiring MERV 1, 2, 3, or 4.

9. Minimum Efficiency Reporting Value and Average Arrestance:

a. MERV Rating and Corresponding Average Arrestance: [**MERV 1**] [**MERV 2**] [**MERV 3**] [**MERV 4**], and corresponding average arrestance according to ASHRAE 52.2.

Retain "Minimum Efficiency Reporting Value" Subparagraph below if inserting requirements for MERV 5 and higher. LEED 2009 Prerequisite IEQ 1 and LEED v4 Prerequisite EQ "Minimum Indoor Air Quality Performance," require compliance with ASHRAE 62.1 (2007 and 2010 versions, respectively), which require a MERV rating of 6 or higher for service to occupied spaces. LEED 2009 IEQ Credit 5 and LEED v4 EQ Credit, "Enhanced Indoor Air Quality Strategies," require MERV 13 or higher. Insert values appropriate to Project sustainability goals.

10. Minimum Efficiency Reporting Value:

a. MERV Rating: [**MERV 6**] [**MERV 13**] <**Insert value**>, according to ASHRAE 52.2.

2.3 MANUFACTURERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.4 UNIT CASINGS

A. General Fabrication Requirements for Casings;

1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
2. Joints: Sheet metal screws or pop rivets.
3. Sealing: Seal all joints with water-resistant sealant. Hermetically seal at each corner and around entire perimeter.
4. Base Rail:

a. Material: [**Galvanized steel**] <**Insert material**>.
b. Height: [**4 inches**] <**Insert dimension**>.

Retain "Single-Wall Construction" or "Double-Wall Construction" Paragraph below.

B. Single-Wall Construction

1. Material: [**Galvanized steel**] <**Insert material**> with [**manufacturer's standard finish**] <**Insert special coating**>.
2. Floor Plate: [**Galvanized steel**] <**Insert material**>, [**treadplate,**]minimum [**18 gauge**] <**Insert value**> thick.
3. Insulation and Adhesive:

a. Materials: [**ASTM C1071, Type I or Type II glass-fiber blanket or board insulation, neoprene coated or foil faced**] <**Insert insulation type**>.
b. Insulation R-Value: Minimum <**Insert value**>.
c. Insulation Thickness: [**1 inch**] <**Insert dimension**>.
d. Thermal Break: Provide continuity of insulation with no through-casing metal in casing walls, floors, or roofs of air-handling unit.
e. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface [**of all complete unit**] [**, downstream from, and including, the cooling coil section**].

1) Liner Adhesive: Comply with ASTM C916, Type I.
2) Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, or mechanical attachment, to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.

C. Double-Wall Construction:

In "Outside Casing Wall" Subparagraph below, not all options are available from all manufacturers; consult manufacturers.

1. Outside Casing Wall: [**Galvanized steel**] <**Insert material**>, minimum [**18 gauge**] <**Insert value**> thick, with [**manufacturer's standard finish**] <**Insert special coating**>.
2. Inside Casing Wall: [**G90 galvanized steel**] <**Insert material**>, [**solid**] [**perforated**], minimum [**18 gauge**] <**Insert value**> thick.
3. Floor Plate: [**G90 galvanized steel**] <**Insert material**>, [**treadplate,**]minimum [**18 gauge**] <**Insert value**> thick.
4. Casing Insulation:

In "Materials" Subparagraph below, not all manufacturers offer each option; consult manufacturers.

a. Materials: [**Glass-fiber blanket or board insulation, Type I or Type II ASTM C1071**] [**or**] [**injected polyurethane foam insulation**].
b. Casing Panel R-Value: Minimum <**Insert value**>.
c. Insulation Thickness: [**1 inch**] <**Insert dimension**>.
d. Thermal Break: Provide continuity of insulation with no through-casing metal in casing walls, floors, or roofs of air-handling unit.

"Airstream Surfaces" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain below to comply with LEED Prerequisite IEQ 1.

D. Airstream Surfaces: Surfaces in contact with airstream shall comply with requirements in ASHRAE 62.1.

E. Static-Pressure Classifications:

1. For Unit Sections Upstream of Fans: Minus [**2-inch wg**] [**3-inch wg**] <**Insert value**>.
2. For Unit Sections Downstream and Including Fans: [**2-inch wg**] [**3-inch wg**] [**4-inch wg**] <**Insert value**>.

F. Panels and Doors:

1. Panels:

a. Fabrication: Formed and reinforced with same materials and insulation thickness as casing.
b. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against airflow.
c. Gasket: Neoprene, applied around entire perimeters of panel frames.
d. Size: Large enough to allow unobstructed access for inspection and maintenance of air-handling unit's internal components. At least [**18 inches**] [**24 inches**] <**Insert dimension**> wide by full height of unit casing up to a maximum height of [**60 inches**] [**72 inches**] <**Insert dimension**>.

2. Doors:

a. Fabrication: Formed and reinforced with same materials and insulation thickness as casing.
b. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against airflow. Provide safety latch retainers on doors so that doors do not open uncontrollably.
c. Gasket: Neoprene, applied around entire perimeters of frame.
d. Size: Large enough to allow for unobstructed access for inspection and maintenance of air-handling unit's internal components. At least [**18 inches**] <**Insert dimension**> wide by full height of unit casing up to a maximum height of [**60 inches**] <**Insert dimension**>.

ASHRAE 62.1, Section "Access for Inspection, Cleaning, and Maintenance," sets requirements for equipment access.

3. Locations and Applications:

Verify that the sections listed below are large enough for access panels and doors.

a. Fan Section: [**Doors**] [**Panels**].
b. Coil Section: Panels.
c. Access Section: [**Doors**] [**Panels**].

d. Access Sections Immediately Upstream and Downstream of Coil Sections: [**Doors**] [**Panels**].
e. Damper Section: [**Doors**] [**Panels**].
f. Filter Section: [**Doors**] [**Panels**] large enough to allow periodic removal and installation of filters.
g. Mixing Section: [**Doors**] [**Panels**].

G. Condensate Drain Pans:

1. Location: Each type of cooling coil.
2. Construction:

a. Single-wall, [**galvanized-steel or noncorrosive polymer**] [**stainless-steel**] sheet.

3. Drain Connection:

a. Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on [**one end**] [**both ends**] of pan.
b. Minimum Connection Size: [**NPS 1**] [**NPS 2**] <**Insert pipe size**>.

Retain last option in "Slope" Subparagraph below to comply with LEED 2009 Prerequisite IEQ 1 or LEED v4 Prerequisite EQ "Minimum Indoor Air Quality Performance" if required by Project requirements or authorities having jurisdiction.

4. Slope: Minimum [**0.125 in./ft.**] <**Insert dimension**> slope[**, to comply with ASHRAE 62.1,**] in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers, and to direct water toward drain connection.

Retain last option in "Length" Subparagraph below to comply with LEED 2009 Prerequisite IEQ 1 or LEED v4 Prerequisite EQ "Minimum Indoor Air Quality Performance" if required by Project requirements or authorities having jurisdiction.

5. Length: Extend drain pan downstream from leaving face [**for distance to comply with ASHRAE 62.1**] <**Insert distance**>.
6. Width: Entire width of water producing device.
7. Depth: A minimum of [**2 inches**] <**Insert dimension**> deep.

2.5 FAN, DRIVE, AND MOTOR SECTION

A. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.

B. Fans: Centrifugal, rated according to AMCA 210; galvanized steel; mounted on solid-steel shaft.

1. Shafts: With field-adjustable alignment.

a. Turned, ground, and polished hot-rolled steel with keyway.

2. Shaft Bearings:

a. Heavy-duty, self-aligning, pillow-block type with an [**L-50**] <**Insert bearing life rating**> rated life of minimum [**100,000**] <**Insert number**> hours according to ABMA 9.

3. Housings: Formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff and spun-metal inlet bell.

a. Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.

4. Housings, Plenum Fans: Steel frame and panel; fabricated without fan scroll and volute housing. Provide inlet screens for Type SWSI fans.

Retain "Forward-Curved, Centrifugal Fan Wheels" or "Airfoil, Centrifugal Fan Wheels (Plenum Fan Wheels)" Subparagraph below if these fan wheels are retained as options in "Capacities and Characteristics" Article.

5. Forward-Curved, Centrifugal Fan Wheels: Inlet flange, backplate, and shallow blades with inlet and tip curved forward in direction of airflow and mechanically fastened to flange and backplate; [**steel**] [**aluminum**] hub swaged to backplate and fastened to shaft with setscrews.
6. Airfoil, Centrifugal Fan Wheels (Plenum Fan Wheels): Smooth-curved inlet flange, backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; steel hub riveted to backplate and fastened to shaft with setscrews.
7. Mounting: For internal vibration isolation[**and seismic control**]. Factory-mount fans with manufacturer's standard[**restrained**] vibration isolation mounting devices having a minimum static deflection of [**1 inch**] <**Insert dimension**>.
8. Shaft Lubrication Lines: Extended to a location outside the casing.

In "Flexible Connector" Subparagraph below, select metal compatible with casing material option selected.

9. Flexible Connector: Factory fabricated with a fabric strip minimum 3-1/2 inches wide, attached to two strips of minimum 2-3/4-inch-wide by 0.028-inch-thick, galvanized-steel sheet.

a. Flexible Connector Fabric: Glass fabric, double coated with neoprene. Fabrics, coatings, and adhesives shall comply with UL 181, Class 1.

C. Drive, Direct: Factory-mounted, direct drive.

D. Drive, Belt: Factory-mounted, V-belt drive, with adjustable alignment and belt tensioning, and with [**1.5**] [**1.25**] service factor based on fan motor.

1. Pulleys: Cast iron or cast steel with split, tapered bushing, dynamically balanced at the factory.
2. Belts: Oil resistant, non-sparking and nonstatic; in matched sets for multiple-belt drives.
3. Belt Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; [**0.146-inch-**] <**Insert dimension**> thick, [**3/4-inch**] <**Insert dimension**> diamond-mesh wire screen, welded to steel angle frame; prime coated.

E. Motors:

Retain first subparagraph below if motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert subparagraphs to suit Project.

1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

Verify enclosure types with manufacturer of specified equipment.

3. Enclosure Type: [**Open, dripproof**] [**Totally enclosed, fan cooled**] <**Insert type**>.

Retain "Enclosure Materials," "Motor Bearings," "Unusual Service Conditions," "Efficiency," and "NEMA Design" subparagraphs below if options are available from equipment manufacturers and are different from default requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment." Consider each subparagraph and retain only those that vary from default requirements.

4. Enclosure Materials: [**Cast iron**] <**Insert material**>.
5. Motor Bearings: <**Insert requirements**>.
6. Unusual Service Conditions:
   a. Ambient Temperature: <**Insert deg C**>.
   b. Altitude: <**Insert feet**> above sea level.
   c. High humidity.
   d. <**Insert conditions**>.
7. Efficiency: Premium efficient as defined in NEMA MG 1.
8. NEMA Design: <**Insert designation**>.

5-hp limit in "Motor Pulleys" Subparagraph below is standard with many manufacturers but is a designer's choice.

9. Motor Pulleys: Adjustable pitch for use with [**5**] <**Insert number**>-hp motors and smaller; fixed pitch for use with motors larger than [**5**] <**Insert number**> hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.
10. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

F. Motors:

First paragraph below is an example of variable-frequency controllers. Retain features and attributes to suit Project, and verify their availability with manufacturers.

Retain one of two "Variable-Frequency Motor Controller" paragraphs below. First paragraph coordinates with electrical variable-frequency motor-control specification. Second paragraph describes basic features of variable-frequency motor controllers and can be used when the variable-frequency motor controller is not on a schedule on Drawings or is different from that specified in variable-frequency motor-controller specification. Coordinate either option with electrical engineer and manufacturers.

G. Variable-Frequency Motor Controller: Comply with Section 262923 "Variable-Frequency Motor Controllers."

H. Variable-Frequency Motor Controller: Serving [**each fan individually**] [**all fans combined**] in fan array.

1. Manufactured Units: Pulse-width modulated; [**constant torque**] [**and**] [**variable torque**] <**Insert application**> for [**Design A and Design B**] [**inverter-duty**] motors.
2. Output Rating: Three phase; 10 to [**60 Hz, with voltage proportional to frequency throughout voltage range**] [**66 Hz, with torque constant as speed changes**]; maximum voltage equals input voltage.
3. Unit Operating Requirements:

a. Internal Adjustability:

1) Minimum Speed: 5 to 25 percent of maximum rpm.
2) Maximum Speed: 80 to 100 percent of maximum rpm.
3) Acceleration: [**0.1 to 999.9**] <**Insert range**> seconds.
4) Deceleration: [**0.1 to 999.9**] <**Insert range**> seconds.
5) Current Limit: 30 to minimum of 150 percent of maximum rating.

b. Self-Protection and Reliability Features:

1) Surge suppression.
2) Loss of input signal protection.
3) Under- and overvoltage trips.
4) Variable-frequency motor controller and motor-overload/overtemperature protection.
5) Critical frequency rejection.
6) Loss-of-phase protection.
7) Reverse-phase protection.
8) Motor-overtemperature fault.

c. Bidirectional autospeed search.
d. Torque boost.
e. Motor temperature compensation at slow speeds.

1) Panel-mounted operator station.
2) Historical logging information and displays.
3) Digital indicating devices.

f. Control Signal Interface: Electric.
g. Proportional Integral Directive (PID) control interface.
h. DDC system for HVAC Protocols for Network Communications: [**ASHRAE 135**] <**Insert protocol type**>.

4. Line Conditioning:

a. Input line conditioning.
b. Output filtering.
c. EMI/RFI filtering.

Insert additional features below after confirming availability from manufacturers.

5. <**Insert features**>.

2.6 COIL SECTION

A. General Requirements for Coil Section:

1. Comply with AHRI 410.
2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
3. Coils shall not act as structural component of unit.

B. Preheat Coils:

Retain "Electrical Coils," "Hot-Water Coils," or "Steam Coils" Subparagraph below for preheat coil type. Not all manufacturers offer electrical coils for preheat; consult manufacturers.

1. Electrical Coils: Comply with UL 1995.

a. Casing Assembly: [**Slip-in**] [**Flanged**] type with galvanized-steel frame.
b. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
c. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from coil section.
d. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
e. Control Panel: [**Unit**] [**Remote**] mounted with disconnecting means and overcurrent protection.

1) [**Magnetic**] [**Mercury**] contactor.
2) Solid-state, stepless pulse controller.
3) Toggle switches, one per step.
4) Step controller.
5) Time-delay relay.
6) Pilot lights, one per step.
7) Airflow proving switch.

In "Hot-Water Coils" Subparagraph below, coordinate type with manufacturers.

2. Hot-Water Coils: [**Continuous circuit**] [**Self-draining**] [**Cleanable**].

a. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
b. Tube Material: [**Copper**] <**Insert material**>.
c. Fin Type: Plate.
d. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
e. Fin Thickness: <**Insert number**> inches.

f. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].

g. Headers:

1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].

2) Seamless copper tube with brazed joints, prime coated.

3) Fabricated steel, with brazed joints, prime coated.

4) Provide insulated cover to conceal exposed outside casings of headers.

h. Frames: Channel frame, minimum 0.052-inch-thick galvanized steel.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

i. Coil Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.

j. Coating: [**None**] [**Corrosion-resistant coating**].

In "Steam Coils" Subparagraph below, coordinate type with manufacturers.

3. Steam Coils: [**Distributed**] [**Single tube**].

a. Steam Outer-Tube Diameter: <**Insert number**> inches.

b. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.

c. Tube Material: [**Copper**] <**Insert material**>.

d. Fin Type: Plate.

e. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.

f. Fin Thickness: <**Insert number**> inches.

g. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].

h. Headers:

1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].

2) Seamless copper tube with brazed joints, prime coated.

3) Fabricated steel, with brazed joints, prime coated.

4) Provide insulated cover to conceal exposed outside casings of headers.

i. Frames: Channel frame, minimum 0.052-inch-thick galvanized steel.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

j. Coil Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.

k. Coating: [**None**] [**Corrosion-resistant coating**].

C. Heating Coils:

Retain "Electrical Coils," "Hot-Water Coils," or "Steam Coils" Subparagraph below for heating coil type.

1. Electrical Coils: Comply with UL 1995.

a. Casing Assembly: [**Slip-in**] [**Flanged**] type with galvanized-steel frame.

b. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
c. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from coil section.
d. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
e. Control Panel: [**Unit**] [**Remote**] mounted with disconnecting means and overcurrent protection.

1) [**Magnetic**] [**Mercury**] contactor.
2) Solid-state, stepless pulse controller.
3) Toggle switches, one per step.
4) Step controller.
5) Time-delay relay.
6) Pilot lights, one per step.
7) Airflow proving switch.

In "Hot-Water Coils" Subparagraph below, coordinate type with manufacturers.

2. Hot-Water Coils: [**Continuous circuit**] [**Self-draining**] [**Cleaning**].

a. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
b. Tube Material: [**Copper**] <**Insert material**>.
c. Fin Type: Plate.
d. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
e. Fin Thickness: <**Insert number**> inches.
f. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].
g. Headers:

1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].
2) Seamless copper tube with brazed joints, prime coated.
3) Fabricated steel, with brazed joints, prime coated.
4) Provide insulated cover to conceal exposed outside casings of headers.

h. Frames: Channel frame, minimum 0.052-inch-thick galvanized steel.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

i. Coil Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.
j. Coating: [**None**] [**Corrosion-resistant coating**].

In "Steam Coils" Subparagraph below, coordinate type with manufacturers.

3. Steam Coils: [**Distributed**] [**Single tube**].

a. Steam Outer-Tube Diameter: <**Insert number**> inches.

b. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
c. Tube Material: [**Copper**] <**Insert material**>.
d. Fin Type: Plate.
e. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
f. Fin Thickness: <**Insert number**> inches.
g. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].
h. Headers:

1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].
2) Seamless copper tube with brazed joints, prime coated.
3) Fabricated steel, with brazed joints, prime coated.
4) Provide insulated cover to conceal exposed outside casings of headers.

i. Frames: Channel frame, minimum 0.052-inch-thick galvanized steel.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

j. Coil Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.
k. Coating: [**None**] [**Corrosion-resistant coating**].

D. Cooling Coils:

Retain "Chilled-Water Coil" or "Refrigerant Coil" Subparagraph below.

In "Chilled-Water Coil" Subparagraph below, coordinate type with manufacturers.

1. Chilled-Water Coil: [**Continuous circuit**] [**Self-draining**] [**Cleanable**].

Retain third option in "Piping Connections" Subparagraph below for freeze protection.

a. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
b. Tube Material: [**Copper**] <**Insert material**>.
c. Tube Thickness: <**Insert number**> inches.
d. Fin Type: Plate.
e. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
f. Fin Thickness: <**Insert number**> inches.
g. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].
h. Headers:

1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].
2) Seamless copper tube with brazed joints, prime coated.
3) Fabricated steel, with brazed joints, prime coated.
4) Provide insulated cover to conceal exposed outside casings of headers.

i. Frames: Channel frame, minimum 0.052-inch-thick galvanized steel.
j. Coatings: [**None**] [**Corrosion-resistant coating**].

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

k. Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.

2. Refrigerant Coil:

a. Tubes: [**Copper**] <**Insert material**>.
b. Fins:

1) Material: [**Aluminum**] <**Insert material**>.

c. Fin and Tube Joints: Mechanical bond.
d. Headers: [**Seamless-copper headers with brazed connections**] <**Insert material and connections**>.
e. Frames: [**Galvanized steel**] <**Insert material frame**>.
f. Coatings: [**None**] [**Corrosion-resistant coating**].
g. Ratings: Designed, tested, and rated according to ASHRAE 33 and AHRI 410.

1) Working Pressure: Minimum 300 psig

2.7 AIR FILTRATION SECTION

Retain one or more of three paragraphs below to require that filters be provided under other filter sections and retain appropriate side access housings to be provided by air-handling manufacturer. Retain applicable filter paragraphs to require that filters be provided by air-handling unit manufacturer. Confirm filter availability with manufacturers.

A. Particulate air filtration is specified in Section 234100 "Particulate Air Filtration."

B. Panel Filters:

1. Description: [**Flat, non-pleated**] [**Pleated**] factory-fabricated, self-supported disposable air filters with holding frames.
2. Filter Unit Class: UL 900.
3. Media: Interlaced glass, synthetic, or cotton fibers coated with nonflammable adhesive and antimicrobial coating.
4. Filter-Media Frame: [**High wet-strength beverage board**] <**Insert material**> with perforated metal retainer, or metal grid, on outlet side.

Retain "Adhesive, Sustainability Projects" Paragraph below if required for sustainability.

C. Adhesive, Sustainability Projects: As recommended by air-filter manufacturer and with a VOC content of 80 g/L or less.

Retain "Adhesive, LEED for Schools Projects" Paragraph below if required for sustainability.

D. Adhesive, LEED for Schools Projects: As recommended by air-filter manufacturer and that complies with the testing and product requirements of the California Department of Public

Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

E. Side-Access Filter Mounting Frames:

1. Particulate Air Filter Frames: Match inner casing and outer casing material, and insulation thickness. [**Galvanized steel**] <**Insert material**> track.

a. Sealing: Incorporate positive-sealing device to ensure seal between gasketed material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

2.8 DAMPERS

Retain "Dampers" Paragraph below if dampers are specified in Section 230923.12 "Control Dampers." Retain "Outdoor- and Return-Air Dampers" Paragraph if dampers are to be provided by unit manufacturer. Not all manufacturers offer this option; consult manufacturers.

A. Dampers: Comply with requirements in Section 230923.12 "Control Dampers."

Low-leakage dampers in "Outdoor- and Return-Air Dampers" Paragraph below are available from most manufacturers and from manufacturers of temperature-control equipment. ASHRAE/IES 90.1 limits maximum damper leakage based on climate zone, number of stories, damper function (intake, exhaust/relief), and damper type (motorized, non-motorized). The most restrictive across all climate zones, number of stories, damper function, and damper type is 4 cfm/sq. ft. (20 L/s per sq. m) at 1-inch wg (250 Pa). This is the maximum leakage cited in paragraph.

B. Outdoor- and Return-Air Dampers: Low-leakage, double-skin, airfoil-blade, [**galvanized-steel**] <**Insert material**> dampers with compressible jamb seals and extruded-vinyl blade edge seals in [**opposed**] [**parallel**]-blade arrangement with [**zinc-plated**]steel operating rods rotating in [**sintered bronze or nylon**] <**Insert material**> bearings mounted in a single [**galvanized-steel**] <**Insert material**> frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed 4 cfm/sq. ft. at 1-inch wg and 8 cfm/sq. ft. at 4-inch wg.

Retain "Damper Operators" Paragraph below if damper operators are specified in Section 230923.12 "Control Dampers." Retain "Electronic Damper Operators" Paragraph to require that damper operators be provided by air-handling unit manufacturer. Not all manufacturers offer this option; consult manufacturers. If retaining second paragraph, coordinate with Division 23 controls Sections for electrical service to devices.

C. Damper Operators: Comply with requirements in Section 230923.12 "Control Dampers."

D. Electronic Damper Operators:

1. Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
2. Electronic damper position indicator shall have visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." Insert subparagraphs to suit Project if different characteristics are required.

3. Operator Motors:

    a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
    b. Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
    c. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.

4. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
5. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running and breakaway torque of 150 in. x lbf.
6. Size dampers for running torque calculated as follows:

    a. Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. of damper.
    b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. of damper.
    c. Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft of damper.
    d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. of damper.
    e. Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm: Increase running torque by 1.5.
    f. Dampers with 3- to 4-Inch wg of Pressure Drop or Face Velocities of 2500 to 3000 fpm: Increase running torque by 2.0.

7. Coupling: V-bolt and V-shaped, toothed cradle.
8. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
9. Fail-Safe Operation: Mechanical, spring-return mechanism with external, manual gear release on nonspring-return actuators.

Coordinate first two subparagraphs and "Proportional Signal" Subparagraph below with Division 23 controls Sections.

10. Power Requirements (Two-Position Spring Return): [**24 V dc**] [**120 V ac**] [**230 V ac**].
11. Power Requirements (Modulating): Maximum 10 VA at 24 V ac or 8 W at 24 V dc.
12. Proportional Signal: 2 to 10 V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
13. Temperature Rating: [**Minus 22 to plus 122 deg F**] [**40 to 104 deg F**].
14. Run Time: [**12 seconds open, 5 seconds closed**] [**30 seconds**] [**60 seconds**] [**120 seconds**].

E. Mixing Section: Multiple-blade, air-mixer assembly located immediately downstream of mixing section.

F. Combination Filter and Mixing Section:

1. Cabinet support members shall hold [**2-inch-**] <**Insert dimension**> thick, pleated, flat, permanent or throwaway filters.

2.9 AIR BLENDERS

A. Multiple-blade, air-mixer assembly shall mix air to prevent stratification, located immediately downstream of mixing box.

2.10 MATERIALS

A. Steel:

1. ASTM A36/A36M for carbon structural steel.
2. ASTM A568/A568M for steel sheet.

B. Stainless Steel:

1. Manufacturer's standard grade for casing.
2. Manufacturer's standard type, ASTM A240/A240M for bare steel exposed to airstream or moisture.

C. Galvanized Steel: ASTM A653/A653M.

D. Aluminum: ASTM B209.

Retain first paragraph below if corrosion-resistant coating is specified in Section 230546 "Coatings for HVAC." Retain "Corrosion-Resistant Coating" Paragraph if corrosion-resistant coating options are cited in "Coil Section" Article and if corrosion-resistant coating is specified in this Section. Determine availability with air-handling unit manufacturers.

E. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating.

F. Corrosion-Resistant Coating: Coat with a corrosion-resistant coating capable of withstanding a [**3000**] <**Insert time**>-hour salt-spray test according to ASTM B117.

1. Standards:

a. ASTM B117 for salt spray.
b. ASTM D2794 for minimum impact resistance of 100 in-lb
c. ASTM B3359 for cross hatch adhesion of 5B.

2. Application: [**Immersion**] [**Spray**].
3. Thickness: [**1 mil**] <**Insert value**>.
4. Gloss: Minimum gloss of 60 on a 60-degree meter.

2.11 SOURCE QUALITY CONTROL

The majority of listed manufacturers are AHRI 430 certified, but a few are not; consult manufacturers. Note that AHRI 430 requires fan performance to be in compliance with AMCA 210.

A. AHRI 430 Certification: Air-handling units and their components shall be factory tested according to AHRI 430 and shall be listed and labeled by AHRI.

Retain "AMCA 300 and AMCA 301, or AHRI 260 Certification" Paragraph below when specifying maximum sound levels. Manufacturers typically offer one certification or the other.

B. AMCA 300 and AMCA 301, or AHRI 260 Certification: Air-handling unit fan sound ratings shall comply with AMCA 300, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data" and AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data," or with AHRI 260, "Sound Rating of Ducted Air Moving and Conditioning Equipment."

C. Water Coils: Factory tested to 300 psig according to AHRI 410 and ASHRAE 33.

D. Steam Coils: Factory tested to 300 psig, and to 200 psig underwater, according to AHRI 410 and ASHRAE 33.

E. Refrigerant Coils: Factory tested to minimum 450-psig internal pressure, and to minimum 300-psig internal pressure while underwater, according to AHRI 410 and ASHRAE 33.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine casing insulation materials and filter media before air-handling unit installation. Replace with new insulation materials and filter media that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for steam, hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

1. Install air-handling units on cast-in-place concrete equipment bases. Coordinate sizes and locations of concrete bases with actual equipment provided. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

Retain one of two subparagraphs below. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device types and minimum deflection in supported equipment schedule on Drawings.

2. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

B. Suspended Units: Suspend[**and brace**] units from structural-steel support frame using threaded steel rods and spring hangers. Coordinate sizes and locations of structural-steel support members with actual equipment provided. Comply with requirements for vibration isolation devices specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]

C. Arrange installation of units to provide access space around air-handling units for service and maintenance.

Sustainable design systems require filters with a minimum MERV 13 rating for air delivered to the occupied space. Air-handling units should not be used for temporary heating and ventilating unless expressly approved by Owner. If used during construction, see SMACNA's "IAQ Guidelines for Occupied Buildings under Construction" for procedures to protect HVAC system.

D. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.

E. Connect duct to air-handling units with flexible connections. Comply with requirements in Section 233300 "Air Duct Accessories."

3.3 PIPING CONNECTIONS

Coordinate piping installations and specialty arrangements with Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to air-handling unit, allow for service and maintenance.

C. Connect piping to air-handling units mounted on vibration isolators with flexible connectors.

D. Connect condensate drain pans using [**NPS 1-1/4**] <**Insert pipe size**>, ASTM B88, Type M copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

E. Hot- and Chilled-Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.

F. Steam and Condensate Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Heating Piping Specialties." Install shutoff valve at steam supply connections, float and thermostatic trap, and union or flange at each coil return connection.

G. Refrigerant Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping." Install shutoff valve and union or flange at each supply and return connection.

3.4 ELECTRICAL CONNECTIONS

A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

C. Install electrical devices furnished by manufacturer, but not factory mounted, according to NFPA 70 and NECA 1.

D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

Retain one of two subparagraphs below. First subparagraph cross-references Section 260553 "Identification for Electrical Systems" and should be retained for consistent electrical identification. Second subparagraph is an abbreviated version of product specified in Section 260553 "Identification for Electrical Systems."

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.5 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring according to Section 260523 "Control-Voltage Electrical Power Cables."

3.6 STARTUP SERVICE

A. [**Engage a factory-authorized service representative to perform**] [**Perform**] startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.

7. Comb coil fins for parallel orientation.
8. Verify that proper thermal-overload protection is installed for electric coils.
9. Install new, clean filters.
10. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.[**Replace fan and motor pulleys as required to achieve design conditions.**]
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.7 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

C. Occupancy Adjustments: When requested within [**12**] <**Insert number**> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <**Insert number**> visits to Project during other-than-normal occupancy hours for this purpose.

3.8 CLEANING

A. After completing system installation and testing, adjusting, and balancing of air-handling unit and air-distribution systems, and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

3.9 FIELD QUALITY CONTROL

Retain one of first four paragraphs below. Retain first "Testing Agency" Paragraph below if Owner will hire an independent testing agency.

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

Retain "Testing Agency" Paragraph below to require Contractor to hire an independent testing agency.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections and retain option to require Contractor to arrange for the assistance of a factory-authorized service agent.

D. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:

1. Leak Test: After installation, fill water and steam coils with water, and test coils and connections for leaks.
2. Charge refrigerant coils with refrigerant and test for leaks.
3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

E. Air-handling unit and components will be considered defective if unit or components do not pass tests and inspections.

F. Prepare test and inspection reports.

3.10 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION 237313.13

SECTION 237313.16 - INDOOR, SEMI-CUSTOM AIR-HANDLING UNITS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

This Section may include provisions for LEED 2009, LEED v4, ASHRAE 189.1, IgCC, and Green Globes. Note that some sustainable design requirements are either mandatory or optional requirements that may be inserted in the Section Text using the hypertext links. Other requirements that are associated with sustainable design, and may be considered "best practice" or retained even if a sustainable design standard is not a project requirement, are discussed in the Evaluations.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes insulated, double-wall-casing, indoor, semi-custom air-handling units that are factory assembled using multiple section components, including the following:

1. Casings.
2. Fans, drives, and motors.
3. Coils.
4. Air filtration.

5. Dampers.
6. Sound attenuators.
7. Humidifiers.
8. Air-to-air energy recovery.
9. Air blender.
10. Diffuser.
11. UV-C lamp systems.

1.3 ACTION SUBMITTALS

A. Product Data: For each air-handling unit.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
3. Include unit dimensions and weight.
4. Include cabinet material, metal thickness, finishes, insulation, and accessories.
5. Fans:

    a. Include certified fan-performance curves with system operating conditions indicated.
    b. Include certified fan-sound power ratings.
    c. Include fan construction and accessories.
    d. Include motor ratings, electrical characteristics, and motor accessories.

6. Include certified coil-performance ratings with system operating conditions indicated.
7. Include filters with performance characteristics.

Retain subparagraph below if items are furnished as parts of air-handling units.

8. Include dampers, including housings, linkages, and operators.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for ASHRAE 62.1.>
2. <Double click to insert sustainable design text for AHU filter performance.>
3. <Double click to insert sustainable design text for adhesives, mastics, and sealants submittals.>

C. Shop Drawings: For each type and configuration of indoor, semi-custom air handling unit.

1. Include plans, elevations, sections, and [**mounting**] [**attachment**] details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Detail fabrication and assembly of indoor, semi-custom air-handling units, as well as procedures and diagrams.
4. Include diagrams for power, signal, and control wiring.

Retain "Delegated-Design Submittal" Paragraph below if design services have been delegated to Contractor. Professional engineer qualifications below are specified in Section 014000 "Quality Requirements."

D. Delegated-Design Submittal: For vibration isolation[**and seismic restraints**] indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Include design calculations for selecting vibration isolators[**and seismic restraints**] and for designing vibration isolation bases.

1.4 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Floor plans and other details, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.

Retain "Seismic Qualification Data" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

B. Seismic Qualification Data: Certificates for air-handling units, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
4. Restraint of internal components.

C. Source quality-control reports.

D. Startup service reports.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

E. Field quality-control reports.

F. Sample Warranty: For manufacturer's warranty.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Filters: [**One**] <**Insert number**> set(s) for each air-handling unit.
2. Gaskets: [**One**] <**Insert number**> set(s) for each access door.
3. Fan Belts: [**One**] <**Insert number**> set(s) for each air-handling unit fan.

1.7 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

A. Warranty: Manufacturer agrees to repair or replace components of indoor, semi-custom air-handling units that fail in materials or workmanship within specified warranty period.

1. Warranty Period: <**Insert number**> year(s) from date of Substantial Completion.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Avitru. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.

"ASHRAE 62.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Sustainable design may require compliance with requirements in ASHRAE 62.1, including requirements for controls, surfaces in contact with the airstream, particulate and gaseous filtration, humidification and dehumidification, drain pan construction and connection, finned-tube coil selection and cleaning, and equipment access. Verify, with manufacturers, the availability of units with components and features that comply with these requirements.

C. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

"ASHRAE/IES 90.1 Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Sustainable design may require minimum efficiency equal to requirements in ASHRAE/IES 90.1.

D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

Retain "Delegated Design" Paragraph below if Contractor is required to assume responsibility for design.

E. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design vibration isolation[**and seismic restraints**], including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

F. Structural Performance: Casing panels shall be self-supporting and capable of withstanding positive/negative [**8-inch wg**] <**Insert value**> of internal static pressure, without exceeding a midpoint deflection of [**0.0042 inch/inch**] <**Insert dimensions**> of panel span.

G. Casing Leakage Performance: ASHRAE 111, [**Class 6 leakage**] <**Insert leakage class**> or better at [**plus or minus 8 inch wg**] <**Insert pressure**>.

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Data" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

H. Seismic Performance: Air-handling units shall withstand the effects of earthquake motions determined according to [**ASCE/SEI 7**] <**Insert requirement**>.

Retain first subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

2. Component Importance Factor: [**1.5**] [**1.0**].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

3. <**Insert requirements for Component Amplification Factor and Component Response Modification Factor**>.

2.2 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of air-handling unit, delete this article and schedule air-handling units on Drawings.

A. Supply Fan:

1. Type: [**DWDI, backward-inclined centrifugal fan**] [**DWDI, forward-curved centrifugal fan**] [**DWDI, airfoil centrifugal fan**] [**SWSI, airfoil unhoused centrifugal fan**] <**Insert fan type**>.

Coordinate "Class" designation in first subparagraph below with fan performance requirements and fan class availability of manufacturers.

2. [**Class I**] [**Class II**] [**Class III**]: AMCA 99-2408.
3. Drive: [**V-belt**] [**Direct**].
4. Number of Fan Wheels: <**Insert number**>.
5. Fan Diameter: <**Insert value**> inches.
6. Airflow: <**Insert value**> cfm.
7. Total Static Pressure: <**Insert value**> inches wg.
8. External Static Pressure: <**Insert value**> inches wg.
9. Speed: <**Insert rpm**>.
10. Maximum Outlet Velocity: <**Insert value**> fpm.
11. Motor:

    a. Size: <**Insert horsepower**>.
    b. Speed: <**Insert rpm**>.
    c. Volts: [**208**] [**230**] [**460**] <**Insert value**> V.
    d. Phase: [**Three**] <**Insert value**>.
    e. Hertz: [**60**] <**Insert number**> Hz.
    f. Full-Load Amperes: <**Insert value**> A.
    g. Minimum Circuit Ampacity: <**Insert value**> A.
    h. Maximum Overcurrent Protection: <**Insert amperage**> A.

12. Fan Discharge Sound Power, dB:

    a. 1st Octave: <**Insert value**>.
    b. 2nd Octave: <**Insert value**>.
    c. 3rd Octave: <**Insert value**>.
    d. 4th Octave: <**Insert value**>.
    e. 5th Octave: <**Insert value**>.
    f. 6th Octave: <**Insert value**>.
    g. 7th Octave: <**Insert value**>.
    h. 8th Octave: <**Insert value**>.

B. [**Return**] [**Exhaust**] Fan:

1. Type: [**DWDI, backward-inclined centrifugal fan**] [**DWDI, forward-curved centrifugal fan**] [**DWDI, airfoil centrifugal fan**] [**SWSI, airfoil unhoused centrifugal plenum fan**] <**Insert fan type**>.
2. [**Class I**] [**Class II**] [**Class III**]: AMCA 99-2408.
3. Drive: [**V-belt**] [**Direct**].
4. Number of Fan Wheels: <**Insert value**>.
5. Fan Diameter: <**Insert value**> inches.
6. Airflow: <**Insert value**> cfm.
7. Total Static Pressure: <**Insert value**> inches wg.
8. External Static Pressure: <**Insert value**> inches wg.
9. Speed: <**Insert rpm**>.
10. Maximum Outlet Velocity: <**Insert value**> fpm.
11. Motor:

    a. Size: <**Insert horsepower**>.
    b. Speed: <**Insert rpm**>.
    c. Volts: [**208**] [**230**] [**460**] <**Insert value**> V.
    d. Phase: [**Three**] <**Insert number**>.
    e. Hertz: [**60**] <**Insert number**> Hz.
    f. Full-Load Amperes: <**Insert value**> A.
    g. Minimum Circuit Ampacity: <**Insert value**> A.
    h. Maximum Overcurrent Protection: <**Insert amperage**> A.
12. Fan Inlet Sound Power, dB:
    a. 1st Octave: <**Insert value**>.
    b. 2nd Octave: <**Insert value**>.
    c. 3rd Octave: <**Insert value**>.
    d. 4th Octave: <**Insert value**>.
    e. 5th Octave: <**Insert value**>.
    f. 6th Octave: <**Insert value**>.
    g. 7th Octave: <**Insert value**>.
    h. 8th Octave: <**Insert value**>.

C. Preheat Coil:

1. Heat-Transfer Rate: <**Insert value**> Btu/h.
2. Entering-Air Temperature: <**Insert value**> deg F.
3. Leaving-Air Temperature: <**Insert value**> deg F.
4. Face Area: <**Insert value**> sq. ft..
5. Maximum Face Velocity: <**Insert value**> fpm.
6. Maximum Air-Side, Static-Pressure Drop: <**Insert value**> inches wg.
7. Fin Spacing: Maximum <**Insert number**> fins per inch.
8. Minimum Number of Rows: <**Insert number**>.

Retain "Integral Face-and-Bypass Dampers" Subparagraph below for integral face-and-bypass dampers on water or steam preheat coils.

9. Integral Face-and-Bypass Dampers: [**Horizontal**] [**Vertical**], opposed-blade, [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] dampers with [**zinc-plated**]steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] frame, with operating rods connected with a common linkage. Meeting edges of blades shall have gaskets and edge seals, and blades shall be mechanically fastened.

10. Water:

    a. Water Flow: <**Insert value**> gpm.
    b. Maximum Water Pressure Drop: <**Insert value**> feet of head.
    c. Entering-Water Temperature: <**Insert value**> deg F.
    d. Leaving-Water Temperature: <**Insert value**> deg F.
    e. Tube Velocity: <**Insert value**> fpm.

11. Steam:

    a. Steam Flow: <**Insert value**> lb/h.
    b. Inlet Steam Pressure: <**Insert value**> psig.
    c. Outer-Tube Diameter: <**Insert value**> inches.

D. Heating Coil:

1. Heat-Transfer Rate: <**Insert value**> Btu/h.
2. Entering-Air Temperature: <**Insert value**> deg F.
3. Leaving-Air Temperature: <**Insert value**> deg F.
4. Face Area: <**Insert value**> sq. ft..
5. Maximum Face Velocity: <**Insert value**> fpm.
6. Maximum Air-Side, Static-Pressure Drop: <**Insert value**> inches wg.
7. Number of Rows: <**Insert number**>.
8. Fin Spacing: Maximum <**Insert number**> fins per inch.
9. Water:

    a. Water Flow: <**Insert value**> gpm.
    b. Maximum Water Pressure Drop: <**Insert value**> feet of head.
    c. Entering-Water Temperature: <**Insert value**> deg F.
    d. Leaving-Water Temperature: <**Insert value**> deg F.
    e. Tube Velocity: <**Insert value**> fpm.

10. Steam:

    a. Steam Flow: <**Insert value**> lb/h.
    b. Inlet Steam Pressure: <**Insert value**> psig.

E. Electric Heating Coil:

1. Heat-Transfer Rate: <**Insert value**> Btu/h.
2. Input: <**Insert kilowatts**>.
3. Volts: [**120**] [**208**] [**230**] <**Insert value**> V.
4. Phase: [**Single**] [**Three**].
5. Full-Load Amperes: <**Insert value**> A.
6. Number of Steps: <**Insert number**>.

F. Cooling Coil:

1. Sensible Heat-Transfer Rate: <**Insert value**> Btu/h.
2. Total Heat-Transfer Rate: <**Insert value**> Btu/h.
3. Entering-Air, Dry-Bulb Temperature: <**Insert value**> deg F.

4. Entering-Air, Wet-Bulb Temperature: <**Insert value**> deg F.
5. Leaving-Air, Dry-Bulb Temperature: <**Insert value**> deg F.
6. Leaving-Air, Wet-Bulb Temperature: <**Insert value**> deg F.
7. Face Area: <**Insert value**> sq. ft..
8. Maximum Face Velocity: <**Insert value**> fpm.
9. Maximum Air-Side, Static-Pressure Drop: <**Insert value**> inches wg.
10. Number of Rows: <**Insert number**>.
11. Fin Spacing: Maximum <**Insert number**> fins per inch.
12. Water:

    a. Water Flow: <**Insert value**> gpm.
    b. Maximum Water Pressure Drop: <**Insert value**> feet of head.
    c. Entering-Water Temperature: <**Insert value**> deg F.
    d. Leaving-Water Temperature: <**Insert value**> deg F.
    e. Tube Velocity: <**Insert value**> fpm.

13. Refrigerant:

    a. Refrigerant Type: <**Insert refrigerant type**>.

G. Prefilters:

1. Type: <**Insert type**>.
2. Face Dimensions, each: <**Insert value**> inches by inches.
3. Depth: <**Insert value**> inches.
4. Number of Filters, Wide by High: <**Insert number**>.
5. Access Location: [**Front**] [**Back**] [**Side**] [**Bottom**].
6. Maximum or Rated Face Velocity: <**Insert value**> fpm.
7. Initial Resistance: <**Insert value**> inches wg.
8. Recommended Final Resistance: <**Insert value**> inches wg.

Retain "Minimum Efficiency Reporting Value and Average Arrestance" Subparagraph below if requiring MERV 1, 2, 3, or 4.

9. Minimum Efficiency Reporting Value and Average Arrestance:

    a. MERV Rating: [**MERV 1**] [**MERV 2**] [**MERV 3**] [**MERV 4**], and corresponding average arrestance according to ASHRAE 52.2.

Retain "Minimum Efficiency Reporting Value" Subparagraph below if inserting requirements for MERV 5 and higher. LEED 2009 Prerequisite IEQ 1 and LEED v4 Prerequisite EQ "Minimum Indoor Air Quality Performance" require compliance with ASHRAE 62.1 (2007 and 2010 versions, respectively), which require a MERV rating of 6 or higher for service to occupied spaces. LEED 2009 IEQ Credit 5 and LEED v4 EQ Credit "Enhanced Indoor Air Quality Strategies" require MERV 13 or higher. Insert values appropriate to Project sustainability goals.

10. Minimum Efficiency Reporting Value:

    a. MERV Rating: [**MERV 6**] [**MERV 13**] <**Insert value**>, according to ASHRAE 52.2.

H. Final Filters:

1. Type: <**Insert type**>.
2. Face Dimensions, each: <**Insert value**> inches by inches.
3. Depth: <**Insert value**> inches.
4. Number of Filters, Wide by High: <**Insert number**>.
5. Access Location: [**Front**] [**Back**] [**Side**] [**Bottom**].
6. Maximum or Rated Face Velocity: <**Insert value**> fpm.
7. Initial Resistance: <**Insert value**> inches wg.
8. Recommended Final Resistance: <**Insert value**> inches wg.

Retain "Minimum Efficiency Reporting Value" Subparagraph below if inserting requirements for MERV 5 and higher. LEED 2009 Prerequisite IEQ 1 and LEED v4 Prerequisite EQ "Minimum Indoor Air Quality Performance" requires compliance with ASHRAE 62.1 (2007 and 2010 versions, respectively), which require a MERV rating of 6 or higher for service to occupied spaces. LEED 2009 IEQ Credit 5 and LEED v4 EQ Credit "Enhanced Indoor Air Quality Strategies" require MERV 13 or higher. Insert values appropriate to Project sustainability goals.

9. Minimum Efficiency Reporting Value:

   a. MERV Rating: [**MERV 6**] [**MERV 13**] <**Insert value**>, according to ASHRAE 52.2.

I. Dampers: [**Zone**] [**Mixing dampers**] [**Face and bypass**].

J. Sound Attenuators:

1. Configuration: [**Straight**] [**Elbow**].
2. Shape: [**Rectangular**] [**Round**].
3. Attenuation Mechanism: [**Acoustic glass fiber**] [**Packless**].
4. Maximum Pressure Drop: <**Insert value**> inches wg.
5. Length: <**Insert value**> inches.
6. Face Dimension: <**Insert value**> inches wide by <**Insert value**> inches high.
7. Face Velocity: <**Insert value**> fpm.
8. Dynamic Insertion Loss:

   a. 1st Octave: <**Insert dBa**>.
   b. 2nd Octave: <**Insert dBa**>.
   c. 3rd Octave: <**Insert dBa**>.
   d. 4th Octave: <**Insert dBa**>.
   e. 5th Octave: <**Insert dBa**>.
   f. 6th Octave: <**Insert dBa**>.
   g. 7th Octave: <**Insert dBa**>.
   h. 8th Octave: <**Insert dBa**>.

9. Generated Noise:

   a. 1st Octave: <**Insert dBa**>.
   b. 2nd Octave: <**Insert dBa**>.
   c. 3rd Octave: <**Insert dBa**>.
   d. 4th Octave: <**Insert dBa**>.
   e. 5th Octave: <**Insert dBa**>.
   f. 6th Octave: <**Insert dBa**>.
   g. 7th Octave: <**Insert dBa**>.

h. 8th Octave: <**Insert dBa**>.

Consult retained air-handling unit manufacturers for humidifier type availability. Retain one of four humidifier types in "Steam Grid Humidifier," "Self-Contained Electric-Resistance Humidifier," "Self-Contained Gas-Fired Humidifier," and "Heat-Exchanger Humidifier" subparagraphs below.

K. Steam Grid Humidifier:

1. Humidification Rate: <**Insert value**> lb/h.
2. Steam Supply Pressure: <**Insert value**> psig.
3. Dry-Bulb Air Temperature at Discharge: <**Insert value**> deg F.
4. Wet-Bulb Air Temperature at Discharge: <**Insert value**> deg F.
5. Maximum Absorption Distance: <**Insert value**> inches.

Retaining "Tubes" or "Manifolds" option in first subparagraph below relates to steam jacketed tubes versus distribution panel manifolds, respectively. See Section 238413.23 for more information. Coordinate with manufacturers.

6. Number of Distribution [**Tubes**] [**Manifolds**]: <**Insert number**>.

L. Self-Contained Electric-Resistance Humidifier.

1. Humidification Rate: <**Insert value**> lb/h.
2. Dry-Bulb Air Temperature at Discharge: <**Insert value**> deg F.
3. Wet-Bulb Air Temperature at Discharge: <**Insert value**> deg F.
4. Maximum Absorption Distance: <**Insert value**> inches.
5. Minimum Makeup Water Supply Pressure: <**Insert value**> psig.
6. Electric-Resistance Evaporation Chamber:

a. Power Input per Chamber: <**Insert number**> kW.
b. Number of Chambers: <**Insert number**>.

M. Self-Contained Gas-Fired Humidifier:

1. Humidification Rate: <**Insert value**> lb/h.
2. Dry-Bulb Air Temperature at Discharge: <**Insert value**> deg F.
3. Wet-Bulb Air Temperature at Discharge: <**Insert value**> deg F.
4. Maximum Absorption Distance: <**Insert value**> inches.
5. Minimum Makeup Water Supply Pressure: <**Insert value**> psig.
6. Gas-Fired Generator:

a. Fuel Input: <**Insert value**> Btu/h.
b. Fuel Pressure: <**Insert value**> inches wg.

7. Number of Distribution [**Tubes**] [**Manifolds**]: <**Insert number**>.

N. Heat-Exchanger Humidifier:

1. Humidification Rate: <**Insert value**> lb/h.
2. Dry-Bulb Air Temperature at Discharge: <**Insert value**> deg F.
3. Wet-Bulb Air Temperature at Discharge: <**Insert value**> deg F.
4. Maximum Absorption Distance: <**Insert value**> inches.

5. Minimum Makeup Water Supply Pressure: <**Insert value**> psig.
6. Steam to Heat Exchanger:

    a. Supply Pressure at Control Valve: <**Insert value**> psig.
    b. Condensing Rate: <**Insert value**> lb/h.

O. Air-to-Air Energy Recovery:

1. Type: [**Heat-wheel air-to-air energy recovery**] [**Fixed-plate air-to-air energy recovery**].
2. Exhaust Air:

    a. Airflow: <**Insert value**> cfm.
    b. Face Velocity: <**Insert value**> fpm.
    c. Summer:
        1) Entering-Air Temperature, Dry Bulb: <**Insert value**> deg F.
        2) Entering-Air Temperature, Wet Bulb: <**Insert value**> deg F.
        3) Leaving-Air Temperature, Dry Bulb: <**Insert value**> deg F.
        4) Leaving-Air Temperature, Wet Bulb: <**Insert value**> deg F.
    d. Winter:
        1) Entering-Air Temperature, Dry Bulb: <**Insert value**> deg F.
        2) Entering-Air Temperature, Wet Bulb: <**Insert value**> deg F.
        3) Leaving-Air Temperature, Dry Bulb: <**Insert value**> deg F.
        4) Leaving-Air Temperature, Wet Bulb: <**Insert value**> deg F.
        5) Air Pressure Drop: <**Insert value**> inches wg.

3. Supply Air:

    a. Airflow: <**Insert value**> cfm.
    b. Face Velocity: <**Insert value**> fpm.
    c. Summer:
        1) Entering-Air Temperature, Dry Bulb: <**Insert value**> deg F.
        2) Entering-Air Temperature, Wet Bulb: <**Insert value**> deg F.
        3) Leaving-Air Temperature, Dry Bulb: <**Insert value**> deg F.
        4) Leaving-Air Temperature, Wet Bulb: <**Insert value**> deg F.
    d. Winter:
        1) Entering-Air Temperature, Dry Bulb: <**Insert value**> deg F.
        2) Entering-Air Temperature, Wet Bulb: <**Insert value**> deg F.
        3) Leaving-Air Temperature, Dry Bulb: <**Insert value**> deg F.
        4) Leaving-Air Temperature, Wet Bulb: <**Insert value**> deg F.
        5) Air Pressure Drop: <**Insert value**> inches wg.

Retain "Wheel Drive" Subparagraph below for heat wheels.

    e. Wheel Drive:
        1) Motor Size: <**Insert horsepower**>.
        2) Motor Electrical Characteristics:
            a) Volts: [**120**] [**208**] [**230**] <**Insert value**> V.
            b) Phase: [**Single**] [**Three**].
            c) Hertz: [**60**] <**Insert number**> Hz.
    f. Effectiveness: <**Insert percentage**>.

4. Air Blender:

   a. Airflow: <**Insert value**> cfm.
   b. Minimum Velocity: <**Insert value**> fpm.
   c. Air Pressure Drop: <**Insert value**> inches wg.

5. Diffuser:

   a. Airflow: <**Insert value**> cfm.
   b. Air Pressure Drop: <**Insert value**> inches wg.

2.3 MANUFACTURERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.4 UNIT CASINGS

A. Frame: Modular and providing overall structural integrity without reliance on casing panels for structural support.

B. Base Rail:

1. Material: [**Galvanized steel**] [**Welded structural steel**] <**Insert material**>.
2. Height: [**6 inches**] <**Insert dimension**>.

C. Casing Joints: Hermetically sealed at each corner and around entire perimeter.

D. Double-Wall Construction:

In "Outside Casing Wall" Paragraph below, not all options are available from all manufacturers; consult manufacturers.

1. Outside Casing Wall:

Retain "Material, Galvanized Steel"; "Material, Aluminum"; or "Material, Stainless Steel" Subparagraph below.

   a. Material, Galvanized Steel: Minimum [**18 gauge**] [**16 gauge**] [**14 gauge**] <**Insert value**> thick.
   b. Material, Aluminum: Minimum [**16 gauge**] [**14 gauge**] [**12 gauge**] <**Insert value**> thick.
   c. Material, Stainless Steel: Minimum [**18 gauge**] [**16 gauge**] [**14 gauge**] <**Insert value**> thick.
   d. Factory Finish: Provide [**manufacturer's standard finish**] <**Insert special coating**>.

In "Inside Casing Wall" Paragraph below, not all options are available from all manufacturers; consult manufacturers.

2. Inside Casing Wall:

Retain "Material, Galvanized Steel"; "Material, Aluminum"; or "Material, Stainless Steel" Subparagraph below.

a. Material, Galvanized Steel: [**Solid**] [**Perforated**], minimum [**18 gauge**] [**16 gauge**] <**Insert value**> thick.
b. Material, Aluminum: [**Solid**] [**Perforated**], minimum [**16 gauge**] [**14 gauge**] <**Insert value**> thick.
c. Material, Stainless Steel: [**Solid**] [**Perforated**], minimum [**18 gauge**] [**16 gauge**] <**Insert value**> thick.
d. Antimicrobial Coating: Applied during the manufacturing process. [**EPA approved**] [**NSF approved**] [**FDA listed**].

In "Floor Plate" Paragraph below, not all options are available from all manufacturers; consult manufacturers.

E. Floor Plate:

1. Material, Galvanized Steel: [**Treadplate,**] minimum [**18 gauge**] [**16 gauge**] [**14 gauge**] [**12 gauge**] [**10 gauge**] <**Insert value**> thick.
2. Material, Aluminum: [**Treadplate,**] minimum [**18 gauge**] [**16 gauge**] [**14 gauge**] [**12 gauge**] [**10 gauge**] <**Insert value**> thick.
3. Material, Stainless Steel: [**Treadplate,**] minimum [**18 gauge**] [**16 gauge**] [**14 gauge**] [**12 gauge**] [**10 gauge**] <**Insert value**> thick.
4. Antimicrobial Coating: Applied during the manufacturing process. [**EPA approved**] [**NSF approved**] [**FDA listed**].

F. Casing Insulation:

The majority of manufacturers now use injected foam insulation. Only a few still offer fiberglass insulation as an option. Be aware that glass fiber performs better acoustically in conjunction with perforated inner casing walls as compared to polyurethane foam. Retain third option in "Materials" Subparagraph below for better sound absorption characteristics of interior perforated sections. Not all manufacturers offer this option; consult manufacturers.

1. Materials: [**Glass-fiber blanket or board insulation, Type I or Type II ASTM C1071**] [**Injected polyurethane foam insulation**] [**Glass-fiber insulation layered over injected foam in perforated interior casing sections to meet specified acoustic requirements**].
2. Casing Panel R-Value: Minimum [**R-11**] [**R-13**] <**Insert value**>.
3. Insulation Thickness: [**2 inches**] <**Insert dimension**>.
4. Thermal Break: Provide continuity of insulation with no through-casing metal in casing walls, floors, or roofs of air-handling unit.

"Airstream Surfaces" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction. Retain below to comply with LEED Prerequisite IEQ 1.

G. Airstream Surfaces: Surfaces in contact with airstream shall comply with requirements in ASHRAE 62.1.

H. Static-Pressure Classifications:

1. For Unit Sections Upstream of Fans: Minus [**2-inch wg**] [**3-inch wg**] [**4-inch wg**] [**6-inch wg**] <**Insert value**>.

2. For Unit Sections Downstream and Including Fans: [**2-inch wg**] [**3-inch wg**] [**4-inch wg**] [**6-inch wg**] <**Insert value**>.

I. Panels, Doors, and Windows:

1. Panels:

a. Fabrication: Formed and reinforced, double-wall and insulated panels of same materials and thicknesses as casing.
b. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against airflow
c. Gasket: Neoprene, applied around entire perimeters of panel frames.
d. Size: Large enough to allow unobstructed access for inspection and maintenance of air-handling unit's internal components. At least [**18 inches**] [**24 inches**] <**Insert dimension**> wide by full height of unit casing up to a maximum height of [**60 inches**] [**72 inches**] <**Insert dimension**>.

2. Doors:

a. Fabrication: Formed and reinforced, double-wall and insulated panels of same materials and thicknesses as casing.
b. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever latches, operable from inside and outside. Arrange doors to be opened against airflow. Provide safety latch retainers on doors so that doors do not open uncontrollably.
c. Gasket: Neoprene, applied around entire perimeters of panel frames.
d. Size: Large enough to allow for unobstructed access for inspection and maintenance of air-handling unit's internal components. At least [**18 inches**] [**24 inches**] <**Insert dimension**> wide by full height of unit casing up to a maximum height of [**60 inches**] [**72 inches**] <**Insert dimension**>.

Retain "Windows" Subparagraph below to add windows in access panels and doors.

3. Windows:

a. Construction: Fabricate windows in access panels and doors of double-glazed, safety glass with an airspace between panes and sealed with interior and exterior rubber seals.
b. Size: Minimum [**6 inches**] <**Insert dimension**>, square or round.

In "Locations and Applications" Subparagraph below, identify sections that are to include windows. ASHRAE 62.1, Section "Access for Inspection, Cleaning, and Maintenance," sets requirements for equipment access.

4. Locations and Applications:

Verify that sections listed below are large enough for access panels and doors.

a. Fan Section: [**Doors**] [**Panels**] [**, with windows**].
b. Coil Section: [**Panels**].
c. Access Section: [**Doors**] [**Panels**] [**, with windows**].

d. Access Sections Immediately Upstream and Downstream of Coil Sections: [**Doors**] [**Panels**] [**, with windows**].

e. Damper Section: [**Doors**] [**Panels**] [**, with viewing windows**].

Retain "Filter Section" Subparagraph below if filter sections are served by side-access housings.

f. Filter Section: [**Doors**] [**Panels**] large enough to allow periodic removal and installation of filters.

Retain first subparagraph below for front- or back-access filter housings.

g. Access Sections Immediately [**Upstream**] [**and**] [**Downstream**] of Filter Sections: [**Doors**] [**Panels**] [**, with windows**].

h. Mixing Section: [**Doors**] [**Panels**] [**, with windows**].

i. Humidifier Section: [**Doors**] [**Panels**] [**, with windows**].

Retain "Service Lights" Subparagraph below to add service lights.

5. Service Lights: <**Insert number of watts**> [**LED**] <**Insert lamp type**> vaporproof luminaire with individual switched junction box located [**outside**] [**inside**], adjacent to each access door and panel.

   a. Locations: [**Each section accessed with door or panel**] [**Fan section**] <**Insert location**>.

6. Convenience Outlets: One 20-A duplex GFCI receptacle per location with junction box located on outside casing wall.

   a. Locations: [**Each section accessed with a door or panel**] [**Fan section**] <**Insert location**>.

J. Condensate Drain Pans:

1. Construction:

Retain one of first two subparagraphs below.

   a. Single-wall, [**galvanized-steel or noncorrosive polymer**] [**stainless-steel**] sheet.

   b. Double-wall, [**galvanized-steel or noncorrosive polymer**] [**stainless-steel**] sheet with space between walls filled with foam insulation and moisture-tight seal.

2. Drain Connection:

   a. Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on [**one end**] [**both ends**] of pan.

   b. Minimum Connection Size: [**NPS 1**] [**NPS 2**] <**Insert pipe size**>.

Retain last option in "Slope" Subparagraph below to comply with LEED 2009 Prerequisite IEQ 1 or LEED v4 Prerequisite EQ "Minimum Indoor Air Quality Performance" if required by Project requirements or authorities having jurisdiction.

3. Slope: Minimum [**0.125-in./ft.**] <**Insert value**> slope[**, to comply with ASHRAE 62.1,**] in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers and to direct water toward drain connection.

Retain option in "Length" Subparagraph below to comply with LEED 2009 Prerequisite IEQ 1 or LEED v4 Prerequisite EQ "Minimum Indoor Air Quality Performance" if required by Project requirements or authorities having jurisdiction.

4. Length: Extend drain pan downstream from leaving face [**for distance to comply with ASHRAE 62.1**] <**Insert distance**>.
5. Width: Entire width of water producing device.
6. Depth: A minimum of [**2 inches**] <**Insert dimension**> deep.
7. [**Formed sections**] [**Integral part of floor plating**].

Retain first subparagraph below for galvanized-steel drain pans.

8. Pan-Top Surface Coating for Galvanized-Steel Drain Pans: Asphaltic waterproofing compound.
9. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

2.5 FAN, DRIVE, AND MOTOR SECTION

A. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.

B. Fans: Centrifugal, rated according to AMCA 210; galvanized steel; mounted on solid-steel shaft.

1. Shafts: With field-adjustable alignment.

    a. Turned, ground, and polished hot-rolled steel with keyway.

2. Shaft Bearings:

Retain "Prelubricated and Sealed, Ball Bearings"; "Grease-Lubricated, Tapered-Roller Bearings"; or "Grease-Lubricated Bearings" Subparagraph below. Other bearing types may be available; those specified below may not be available from all manufacturers.

    a. Prelubricated and Sealed, Ball Bearings: Self-aligning, pillow-block type with an [**L-50**] <**Insert bearing life rating**> rated life of [**200,000**] <**Insert number**> hours according to ABMA 9.
    b. Grease-Lubricated, Tapered-Roller Bearings: Self-aligning, pillow-block type with double-locking collars and two-piece, cast-iron housing[**with grease lines extended to outside unit**] and an [**L-50**] <**Insert bearing life rating**> rated life of [**200,000**] <**Insert number**> hours according to ABMA 11.
    c. Grease-Lubricated Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing[**with grease lines extended to outside unit**] and an [**L-50**] <**Insert bearing life rating**> rated life of [**200,000**] <**Insert number**>.

3. Housings: Formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff and spun-metal inlet bell.

    a. Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.

4. Housings, Plenum Fans: Steel frame and panel; fabricated without fan scroll and volute housing. Provide inlet screens for Type SWSI fans.

In "Plenum Fan Arrays" Subparagraph below, retain one of first two options. These are AHRI 430 terminology. Contained fan arrays have uniform partitioning enclosures between the sides of fans, and, as a result, fans do not aerodynamically interact. Uncontained fan arrays do not have partitioning enclosures between the sides of fans, and, as a result, fans do aerodynamically interact. Coordinate selection with manufacturers.

5. Plenum Fan Arrays: [**Contained**] [**Uncontained**] as defined in AHRI 430. Steel or aluminum frame with inlet cone and structural framing around each fan built into an array of multiple fans. Provide [**backdraft**] [**motorized**] dampers at each fan to prevent short circuiting of flow if one fan is not operating.

Retain "Backward-Inclined, Centrifugal Fan Wheels"; Forward-Curved, Centrifugal Fan Wheels"; or "Airfoil, Centrifugal Fan Wheels (Plenum Fan Wheels)" Subparagraph below if these fan wheels are retained as options in "Capacities and Characteristics" Article.

6. Backward-Inclined, Centrifugal Fan Wheels: Construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; [**steel**] [**aluminum**] hub riveted to backplate and fastened to shaft with setscrews.
7. Forward-Curved, Centrifugal Fan Wheels: Inlet flange, backplate, and shallow blades with inlet and tip curved forward in direction of airflow and mechanically fastened to flange and backplate; [**steel**] [**aluminum**] hub swaged to backplate and fastened to shaft with setscrews.
8. Airfoil, Centrifugal Fan Wheels (Plenum Fan Wheels): Smooth-curved inlet flange, backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; steel hub riveted to backplate and fastened to shaft with setscrews.
9. Mounting: For internal vibration isolation[**and seismic control**]. Factory-mount fans with manufacturer's standard[**restrained**] vibration isolation mounting devices having a minimum static deflection of [**1 inch**] [**2 inches**] <**Insert dimension**>.
10. Shaft Lubrication Lines: Extended to a location outside the casing.

In "Flexible Connector" Subparagraph below, select metal compatible with casing material option selected.

11. Flexible Connector: Factory fabricated with a fabric strip minimum [**3-1/2 inches**] [**5-3/4 inches**] <**Insert dimension**> wide, attached to two strips of minimum [**2-3/4-inch-wide**] <**Insert dimension**> by [**0.028-inch-thick, galvanized-steel sheet**] [**0.032-inch-thick, aluminum sheets**].

    a. Flexible Connector Fabric: Glass fabric, double coated with neoprene. Fabrics, coatings, and adhesives shall comply with UL 181, Class 1.

        1) Fabric Minimum Weight: 26 oz./sq. yd..
        2) Fabric Minimum Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
        3) Fabric Minimum Service Temperature Range: Minus 40 to plus 200 deg F.

C. Drive, Direct: Factory-mounted, direct drive.

D. Drive, Belt: Factory-mounted, V-belt drive, with adjustable alignment and belt tensioning, and with [**1.5**] [**1.25**] service factor based on fan motor.

1. Pulleys: Cast iron or cast steel with split, tapered bushing, dynamically balanced at the factory.
2. Belts: Oil resistant, non-sparking and nonstatic; in matched sets for multiple-belt drives.
3. Belt Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; [**0.146-inch-**] <**Insert dimension**> thick, [**3/4-inch**] <**Insert dimension**> diamond-mesh wire screen, welded to steel angle frame; prime coated

E. Motors:

Retain first subparagraph below if motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs to suit Project.

1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
2. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

Verify enclosure types with manufacturer of specified equipment.

3. Enclosure Type: [**Open, dripproof**] [**Totally enclosed, fan cooled**] <**Insert type**>.

Retain "Enclosure Materials," "Motor Bearings," "Unusual Service Conditions," "Efficiency," and "NEMA Design" subparagraphs below if options are available from equipment manufacturers and are different from default requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment." Consider each subparagraph and retain only those that vary from default requirements.

4. Enclosure Materials: [**Cast iron**] <**Insert material**>.
5. Motor Bearings: <**Insert requirements**>.
6. Unusual Service Conditions:

    a. Ambient Temperature: <**Insert deg C**>.
    b. Altitude: <**Insert feet**> above sea level.
    c. High humidity.
    d. <**Insert conditions**>.
7. Efficiency: Premium Efficient motors as defined in NEMA MG 1.
8. NEMA Design: <**Insert designation**>.

5-hp limit in "Motor Pulleys" Subparagraph below is standard with many manufacturers but is a designer's choice.

1. Motor Pulleys: Adjustable pitch for use with [**5**] <**Insert number**>-hp motors and smaller; fixed pitch for use with motors larger than [**5**] <**Insert number**> hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

If unique characteristics are required for motors in this Section, insert subparagraphs below.

3. <**Insert unique motor characteristics**>.

Retain first subparagraph below to require that disconnect switches be supplied with unit.

4. Mount unit-mounted disconnect switches on [**exterior**] [**interior**] of unit.

First paragraph below is an example of variable-frequency controllers. Retain features and attributes to suit Project, and verify their availability with manufacturers.

Retain one of two "Variable-Frequency Motor Controller" paragraphs below. First paragraph coordinates with electrical variable-frequency motor-control specification. Second paragraph describes basic features of variable-frequency motor controllers and can be used when variable-frequency motor controller is not on a schedule on Drawings or is different from that specified in variable-frequency motor-controller specification. Coordinate either option with electrical engineer and manufacturers.

F. Variable-Frequency Motor Controller: Comply with Section 262923 "Variable-Frequency Motor Controllers."

G. Variable-Frequency Motor Controller: Serving [**each fan individually**] [**all fans combined**] in fan array.

1. Manufactured Units: Pulse-width modulated; [**constant torque**] [**and**] [**variable torque**] <**Insert application**> for [**Design A and Design B**] [**inverter-duty**] motors.
2. Output Rating: Three phase; 10 to [**60 Hz, with voltage proportional to frequency throughout voltage range**] [**66 Hz, with torque constant as speed changes**]; maximum voltage equals input voltage.
3. Unit Operating Requirements:

a. Internal Adjustability:
1) Minimum Speed: 5 to 25 percent of maximum rpm.
2) Maximum Speed: 80 to 100 percent of maximum rpm.
3) Acceleration: [**0.1 to 999.9**] <**Insert range**> seconds.
4) Deceleration: [**0.1 to 999.9**] <**Insert range**> seconds.
5) Current Limit: 30 to minimum of 150 percent of maximum rating.
b. Self-Protection and Reliability Features:
1) Surge suppression.
2) Loss of input signal protection.
3) Under- and overvoltage trips.
4) Variable-frequency motor controller and motor-overload/overtemperature protection.
5) Critical frequency rejection.
6) Loss-of-phase protection.
7) Reverse-phase protection.
8) Motor-overtemperature fault.
c. Bidirectional autospeed search.
d. Torque boost.
e. Motor temperature compensation at slow speeds.
1) Panel-mounted operator station.
2) Historical logging information and displays.
3) Digital indicating devices.
f. Control Signal Interface: Electric.
g. Proportional Integral Directive (PID) control interface.
h. DDC system for HVAC Protocols for Network Communications: [**ASHRAE 135**] <**Insert protocol type**>.

4. Line Conditioning:

   a. Input line conditioning.
   b. Output filtering.
   c. EMI/RFI filtering.

Bypass is not available from all manufacturers; consult manufacturers.

5. Bypass Systems:

   a. Bypass Mode: [**Manual operation only**] [**Field-selectable automatic or manual**].

Retain one of two "Bypass Controller" subparagraphs below. Bypass is not available from all manufacturers; consult manufacturers.

   b. Bypass Controller: Two-contactor style, with bypass and output isolating contactors[**and isolating switch**].
   c. Bypass Controller: Three-contactor style, with bypass and input and output isolating contactors[**and isolating switch**].
   d. Bypass Contactor Configuration: [**Full-voltage (across the line)**] [**Reduced-voltage (autotransformer)**] <**Insert type**> type.

2.6 COIL SECTION

A. General Requirements for Coil Section:

1. Comply with AHRI 410.
2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
3. For multizone units, provide air deflectors and air baffles to balance airflow across coils.
4. Coils shall not act as structural component of unit.

B. Preheat Coils:

Retain preheat coil types from subparagraphs below.

1. Electrical Coils, Controls, and Accessories: Comply with UL 1995.

   a. Casing Assembly: [**Slip-in**] [**Flanged**] type with galvanized-steel frame.

Lack of manufacturer availability of sheathed type. Therefore, sheathed type was not included as an option.

   b. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
   c. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from coil section.
   d. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.

e. Control Panel: [**Unit**] [**Remote**] mounted with disconnecting means and overcurrent protection.
   1) [**Magnetic**] [**Mercury**] contactor.
   2) Solid-state, stepless pulse controller.
   3) Toggle switches, one per step.
   4) Step controller.
   5) Time-delay relay.
   6) Pilot lights, one per step.
   7) Airflow proving switch.

In "Hot-Water Coils" Subparagraph below, coordinate type with manufacturers.

2. Hot-Water Coils: [**Continuous circuit**] [**Self-draining**] [**Cleanable**].

a. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
b. Tube Material: [**Copper**] <**Insert material**>.
c. Fin Type: Plate.
d. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
e. Fin Spacing: Maximum [**10**] [**12**] <**Insert spacing**> fins per inch.
f. Fin Thickness: <**Insert value**> inches.
g. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].
h. Headers:
   1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].
   2) Seamless copper tube with brazed joints, prime coated.
   3) Fabricated steel, with brazed joints, prime coated.
   4) Provide insulated cover to conceal exposed outside casings of headers.
i. Frames: Channel frame, [**0.052-inch-thick, galvanized steel**] [**0.064-inch-thick, galvanized steel**] [**0.079-inch-thick, galvanized steel**] [**0.0625-inch-thick, galvanized steel**] [**0.0625-inch-thick, stainless steel**] <**Insert thickness**> <**Insert material**>.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

j. Coil Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.
k. Coating: [**None**] [**Corrosion-resistant coating**].

Retain first subparagraph below for integral face-and-bypass dampers on water or steam coils.

l. Integral Face-and-Bypass Dampers: [**Horizontal**] [**Vertical**], opposed-blade, [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] dampers with [**zinc-plated**]steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] frame, with operating rods connected with a common linkage. Meeting edges of blades shall have gaskets and edge seals, and blades shall be mechanically fastened.

3. Steam Coils: [**Distributed**] [**Single tube**].

a. Steam Outer-Tube Diameter: <**Insert value**> inches.
b. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
c. Tube Material: [**Copper**] <**Insert material**>.
d. Fin Type: Plate.

e. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
f. Fin Spacing: Maximum [**8**] [**10**] [**12**] <**Insert spacing**> fins per inch.
g. Fin Thickness: <**Insert value**> inches.
h. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].
i. Headers:
   1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].
   2) Seamless copper tube with brazed joints, prime coated.
   3) Fabricated steel, with brazed joints, prime coated.
   4) Provide insulated cover to conceal exposed outside casings of headers.
j. Frames: Channel frame, [**0.052-inch-thick, galvanized steel**] [**0.064-inch-thick, galvanized steel**] [**0.079-inch-thick, galvanized steel**] [**0.0625-inch-thick, galvanized steel**] [**0.0625-inch-thick, stainless steel**] <**Insert thickness**> <**Insert material**>.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

k. Coil Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.
l. Coating: [**None**] [**Corrosion-resistant coating**].

Retain subparagraph below for integral face-and-bypass dampers on water or steam coils.

m. Integral Face-and-Bypass Dampers: [**Horizontal**] [**Vertical**], opposed-blade, [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] dampers with [**zinc-plated**]steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] frame, with operating rods connected with a common linkage. Meeting edges of blades shall have gaskets and edge seals, and blades shall be mechanically fastened.

C. Heating Coils:

1. Electrical Coils, Controls, and Accessories: Comply with UL 1995.

a. Casing Assembly: [**Slip-in**] [**Flanged**] type with galvanized-steel frame.

Lack of manufacturer availability for sheathed type; therefore, sheathed type was not included as an option.

b. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
c. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from coil section.
d. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
e. Control Panel: [**Unit**] [**Remote**] mounted with disconnecting means and overcurrent protection.
   1) [**Magnetic**] [**Mercury**] contactor.
   2) Solid-state, stepless pulse controller.
   3) Toggle switches, one per step.

4) Step controller.
5) Time-delay relay.
6) Pilot lights, one per step.
7) Airflow proving switch.

In "Hot-Water Coils" Subparagraph below, coordinate type with manufacturers.

2. Hot-Water Coils: [**Continuous circuit**] [**Self-draining**] [**Cleaning**].

a. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
b. Tube Material: [**Copper**] <**Insert material**>.
c. Fin Type: Plate.
d. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
e. Fin Spacing: Maximum [**10**] [**12**] <**Insert spacing**> fins per inch.
f. Fin Thickness: <**Insert value**> inches.
g. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].
h. Headers:
    1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].
    2) Seamless copper tube with brazed joints, prime coated.
    3) Fabricated steel, with brazed joints, prime coated.
    4) Provide insulated cover to conceal exposed outside casings of headers.
i. Frames: Channel frame, [**0.052-inch-thick, galvanized steel**] [**0.064-inch-thick, galvanized steel**] [**0.079-inch-thick, galvanized steel**] [**0.0625-inch-thick, galvanized steel**] [**0.0625-inch-thick, stainless steel**] <**Insert thickness**> <**Insert material**>.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

j. Coil Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.
k. Coating: [**None**] [**Corrosion-resistant coating**].

In "Steam Coils" Subparagraph below, coordinate type with manufacturers.

3. Steam Coils: [**Distributed**] [**Single tube**].

a. Steam Outer-Tube Diameter: <**Insert value**> inches.
b. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
c. Tube Material: [**Copper**] <**Insert material**>.
d. Fin Type: Plate.
e. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
f. Fin Spacing: Maximum [**10**] [**12**] <**Insert spacing**> fins per inch.
g. Fin Thickness: <**Insert value**> inches.
h. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].
i. Headers:
    1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].
    2) Seamless copper tube with brazed joints, prime coated.
    3) Fabricated steel, with brazed joints, prime coated.
    4) Provide insulated cover to conceal exposed outside casings of headers.
j. Frames: Channel frame, [**0.052-inch-thick, galvanized steel**] [**0.064-inch-thick, galvanized steel**] [**0.079-inch-thick, galvanized steel**] [**0.0625-inch-thick,**

galvanized steel] [**0.0625-inch-thick, stainless steel**] <**Insert thickness**> <**Insert material**>.

Pressure and temperature ratings in first subparagraph below are standard for most copper tube coils. Other materials have different ratings.

k. Coil Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.
l. Coating: [**None**] [**Corrosion-resistant coating**].

D. Cooling Coils:

Retain "Chilled-Water Coil" or "Refrigerant Coil" Subparagraph below.

1. Chilled-Water Coil: [**Continuous circuit**] [**Self-draining**] [**Cleanable**].

Retain third option in "Piping Connections" Subparagraph below for freeze protection.

a. Piping Connections: [**Threaded**] [**Flanged**], [**same end**] [**opposite ends**] of coil.
b. Tube Material: [**Copper**] <**Insert material**>.
c. Tube Thickness: <**Insert value**> inches.
d. Fin Type: Plate.
e. Fin Material: [**Aluminum**] [**Copper**] <**Insert material**>.
f. Fin Spacing: [**0.125 inch**] [**0.091 inch**] [**0.071 inch**] [**0.067 inch**] [**0.056 inch**] [**0.0075 inch**] <**Insert fins per inch**>.
g. Fin Thickness: <**Insert value**> inches.
h. Fin and Tube Joint: [**Mechanical bond**] [**Silver brazed**].
i. Headers:
   1) Cast iron with[**cleaning plugs and**] drain and air vent tappings[**extended to exterior of unit**].
   2) Seamless copper tube with brazed joints, prime coated.
   3) Fabricated steel, with brazed joints, prime coated.
   4) Provide insulated cover to conceal exposed outside casings of headers.
j. Frames: Channel frame, [**0.052-inch-thick, galvanized steel**] [**0.064-inch-thick, galvanized steel**] [**0.079-inch-thick, galvanized steel**] [**0.0625-inch-thick, galvanized steel**] [**0.0625-inch-thick, stainless steel**].
k. Coatings: [**None**] [**Corrosion-resistant coating**].

Pressure and temperature ratings in "Working-Pressure Ratings" Subparagraph below are standard for most copper tube coils. Other materials have different ratings.

l. Working-Pressure Ratings: [**200 psig, 325 deg F**] <**Insert value and temperature**>.

Sustainable design systems require using CFC-free refrigerants in new HVAC&R systems.

2. Refrigerant Coil:

a. Tubes: [**Copper**] <**Insert material**>.
b. Fins:
   1) Material: [**Aluminum**] [**Copper**] <**Insert material**>.
   2) Fin Spacing: Maximum [**12**] [**10**] [**8**] <**Insert spacing**> fins per inch.
c. Fin and Tube Joints: Mechanical bond.
d. Headers: [**Seamless-copper headers with brazed connections**] <**Insert material and connections**>.
e. Frames: [**Galvanized steel**] [**Stainless steel**] <**Insert material frame**>.

f. Coatings: [**None**] [**Corrosion-resistant coating**].
g. Ratings: Designed, tested, and rated according to ASHRAE 33 and AHRI 410.
1) Working Pressure: Minimum 300 psig.

2.7 AIR FILTRATION SECTION

Retain one or more of first three paragraphs below to require that filters be provided under other filter Sections, and retain appropriate mounting frame or side-access housings to be provided by air-handling manufacturer. Retain applicable filter paragraphs to require that filters be provided by air-handling unit manufacturer. Most air-handling manufacturers do not offer gas-phase filters as part of air-handling unit. Confirm availability with manufacturers.

A. Particulate air filtration is specified in Section 234100 "Particulate Air Filtration."

B. High-efficiency particulate air (HEPA) filtration is specified in Section 234133 "High-Efficiency Particulate Air Filtration."

C. Gas-phase air filtration is specified in Section 234200 "Gas-Phase Air Filtration."

D. Panel Filters:

1. Description: [**Flat, non-pleated**] [**Pleated**] factory-fabricated, self-supported, disposable air filters with holding frames.
2. Filter Unit Class: UL 900.
3. Media: Interlaced glass, synthetic or cotton fibers coated with nonflammable adhesive.
4. Filter-Media Frame: [**Beverage board**] <**Insert material**> with perforated metal retainer, or metal grid, on outlet side.

E. Bag Filters:

1. Description: Factory-fabricated, dry, extended-surface, self-supporting filters with holding frames in steel, basket-type retainers.
2. Filter Unit Class: UL 900.
3. Media: Fibrous material, coated with antimicrobial agent, constructed so individual pockets are maintained in tapered form by flexible internal supports under rated-airflow conditions.
4. Filter-Media Frame: [**Galvanized steel**] <**Insert material**>.

F. Cartridge Filters:

1. Description: Factory-fabricated, [**adhesive-coated**]disposable, packaged air filters with media perpendicular to airflow, and with holding frames.
2. Filter Unit Class: UL 900.
3. Media: Fibrous material, coated with antimicrobial agent, constructed so individual pleats are maintained in pleated form under rater-airflow conditions by corrugated aluminum separators.
4. Filter Media Frame: [**Galvanized steel**] <**Insert material**>.

Retain "Adhesive, Sustainability Projects" Paragraph below if required for sustainability.

G. Adhesive, Sustainability Projects: As recommended by air-filter manufacturer and with a VOC content of 80 g/L or less.

Retain "Adhesive, LEED for Schools Projects" Paragraph below if required for sustainability.

H. Adhesive, LEED for Schools Projects: As recommended by air-filter manufacturer and that complies with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

Retain "(Front-) (or) (Back-)Access Filter Mounting Frames" or "Side-Access Filter Mounting Frames" Paragraph below to reflect type of filter access desired.

I. [**Front-**] [**or**] [**Back-**]Access Filter Mounting Frames:

Retain one or more of three subparagraphs below to match filter types.

1. Particulate Air Filter Frames: [**Galvanized-steel**] [**Aluminum**] framing members with access for filter servicing, cut to size and prepunched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.

   a. Prefilters: Incorporate a separate [**2-inch-**] <**Insert dimension**> thick track[**with spring clips**], with same access as primary filter.
   b. Sealing: Full periphery foam gaskets.

2. HEPA Filter Frames: [**Aluminum**] [**Stainless-steel**] framing members, cut to size and prepunched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation operation. Bolted filter-sealing mechanism shall mount and continuously seal each individual filter.

   a. Prefilters: Incorporate a separate [**2-inch-**] [**4-inch-**] <**Insert dimension**> thick track[**with spring clips**] with same access as primary filter.
   b. Sealing: [**Gasketed**] [**or**] [**gel**], hand-crank locking mechanism to provide positive-sealing for each filter to ensure seal between filter elements to prevent bypass of unfiltered air.

Retain "Gas-Phase Air Filter Frames" Subparagraph below for front or back access of gas-phase air filters.

3. Gas-Phase Air Filter Frames: [**Galvanized-steel**] [**Aluminum**] framing members with access for filter servicing, cut to size and prepunched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.

   a. Prefilters: Incorporate a separate [**2-inch-**] <**Insert dimension**> thick track[**with spring clips**].
   b. Sealing: [**Full periphery foam gaskets**] [**Positive-sealing-device for each row of filters to ensure seal between gasketed filter elements to prevent bypass of unfiltered air**].

J. Side-Access Filter Mounting Frames:

Retain one or more of three subparagraphs below to match filter types.

1. Particulate Air Filter Frames: Match inner casing and outer casing material, and insulation thickness. [**Galvanized steel**] [**Aluminum**] track.

   a. Prefilters: Incorporate an integral [**2-inch-**] <**Insert dimension**> thick track with same access as primary filter.
   b. Sealing: Incorporate positive-sealing device to ensure seal between gasketed material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

2. HEPA Filter Frames:

   a. Frames: Match inner casing and outer casing material, and insulation thickness. [**Aluminum**] [**Stainless steel**] track.
   b. Prefilters: Incorporate an integral [**2-inch-**] [**4-inch-**] <**Insert dimension**> thick track,
   c. Sealing: Incorporate positive-sealing clamping device on each filter between [**gasket**] [**gel**] seal on all sides of filter cartridge frames to prevent bypass of unfiltered air.

3. Gas-Phase Air Filter Frames:

   a. Frames: Matching inner casing and outer casing material, and insulation thickness. [**Galvanized-steel**] [**Aluminum**] track.
   b. Prefilters: Incorporate an integral [**2-inch-**] <**Insert dimension**> thick track.
   c. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

2.8 DAMPERS

Retain "Dampers" Paragraph below if dampers are specified in Section 230923.12 "Control Dampers." Retain "Outdoor- and Return-Air Dampers," "Face-and-Bypass Dampers," and "Zone Dampers" paragraphs if dampers are to be provided by unit manufacturer. Not all manufacturers offer this option; consult manufacturers.

A. Dampers: Comply with requirements in Section 230923.12 "Control Dampers."

Low-leakage dampers in "Outdoor- and Return-Air Dampers" Paragraph below are available from most manufacturers and from manufacturers of temperature-control equipment. ASHRAE/IES 90.1 limits maximum damper leakage based on climate zone, number of stories, damper function (intake, exhaust/relief), and damper type (motorized, non-motorized). The most restrictive across all climate zones, number of stories, damper function, and damper type is 4 cfm/sq. ft. (20 L/s per sq. m) at 1-inch wg (250 Pa). This is the maximum leakage cited in paragraph.

B. Outdoor- and Return-Air Dampers: Low-leakage, double-skin, airfoil-blade, [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] <**Insert material**> dampers with compressible jamb seals and extruded-vinyl blade edge seals in [**opposed**] [**parallel**]-blade arrangement with [**zinc-plated**]steel operating rods rotating in [**stainless steel sleeve**] [**sintered bronze or nylon**] <**Insert material**> bearings mounted in a single [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] <**Insert material**> frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed [**4 cfm/sq. ft. at 1-inch wg and 8 cfm/sq. ft. at 4-inch wg**] <**Insert requirement**>.

C. Face-and-Bypass Dampers: Opposed-blade, [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] dampers with [**zinc-plated**]steel operating rods rotating in sintered bronze or nylon bearings mounted in a single [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] frame and with operating rods connected with a common linkage. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

D. Zone Dampers: Two single-blade, [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] <**Insert materials**> dampers offset 90 degrees from each other on [**zinc-plated**]steel operating rod rotating in sintered bronze or nylon bearings mounted in a single [**galvanized-steel**] [**aluminum**] [**extruded-aluminum**] <**Insert material**> frame. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

Retain "Damper Operators" Paragraph below if damper operators are specified in Section 230923.12 "Control Dampers." Retain "Electronic Damper Operators" Paragraph to require that damper operators be provided by air-handling unit manufacturer. If retaining second paragraph, coordinate with Division 23 controls Sections for electrical service to devices.

E. Damper Operators: Comply with requirements in Section 230923.12 "Control Dampers."

F. Electronic Damper Operators:

1. Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
2. Electronic damper position indicator shall have visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." Insert subparagraphs to suit Project if different characteristics are required.

3. Operator Motors:

   a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
   b. Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
   c. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.

4. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
5. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running and breakaway torque of 150 in. x lbf.
6. Size dampers for running torque calculated as follows:

   a. Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. of damper.
   b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. of damper.
   c. Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft of damper.

d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. of damper.
e. Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm: Increase running torque by 1.5.
f. Dampers with 3- to 4-Inch wg of Pressure Drop or Face Velocities of 2500 to 3000 fpm: Increase running torque by 2.0.

7. Coupling: V-bolt and V-shaped, toothed cradle.
8. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
9. Fail-Safe Operation: Mechanical, spring-return mechanism with external, manual gear release on nonspring-return actuators.

Coordinate first two subparagraphs and "Proportional Signal" Subparagraph below with Division 23 controls Sections.

10. Power Requirements (Two-Position Spring Return): [**24 V dc**] [**120 V ac**] [**230 V ac**].
11. Power Requirements (Modulating): Maximum 10 VA at 24 V ac or 8 W at 24 V dc.
12. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
13. Temperature Rating: [**Minus 22 to plus 122 deg F**] [**40 to 104 deg F**].
14. Run Time: [**12 seconds open, 5 seconds closed**] [**30 seconds**] [**60 seconds**] [**120 seconds**].

G. Mixing Section: Multiple-blade, air-mixer assembly located immediately downstream of mixing section.

H. Combination Filter and Mixing Section:

1. Cabinet support members shall hold [**2-inch-**] <**Insert dimension**> thick, pleated, flat, permanent or throwaway filters.
2. Multiple-blade, air-mixer assembly shall mix air to prevent stratification, located immediately downstream of mixing box.

2.9 SOUND ATTENUATORS

Sound attenuators are available from several, but not all, manufacturers; consult manufacturers.

A. General Requirements:

1. Factory fabricated.
2. Fire Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials with flame-spread index not exceeding 25 and smoke-developed index not exceeding 50, ASTM E84.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with ASHRAE 62.1.

B. Shape: [**Rectangular, straight**] [**Round, straight**] [**Rectangular, elbow**] [**Round, elbow**].

C. Rectangular Silencer Outer Casing: [**Galvanized steel**] <**Insert material**>.

D. Round Silencer Outer Casing: [**Galvanized steel**] <**Insert material**>.

E. Inner Casing and Baffles: [**Galvanized steel**] <**Insert material**>.

F. Principal Sound-Absorbing Mechanism:

Retain "Packless Type" or "Dissipative Type" Subparagraph below. Packless types use controlled impedance to reduce sound with no absorptive fill. They are used in sensitive applications where no airstream contact to absorptive material is desired. Film-lined option of dissipative type can provide some protection against direct contact between absorptive material and the airstream.

1. Packless Type: Controlled impedance membranes and broadly tuned resonators without adsorptive media.
2. Dissipative Type: [**Polymer film-lined**]absorptive fill material.

    a. Fill Material: [**Inert and vermin-proof fibrous material**] <**Insert material type**>.

3. Joints: Lock formed and sealed, continuously welded or flanged.

2.10 HUMIDIFIERS

Retain this article to require that humidifiers be provided by air-handling unit manufacturer and to reference applicable humidifier Section. If only certain humidifier features are desired, cut and paste from one of the five humidifier Sections into this article. Not all manufacturers offer each type of humidifier. Confirm availability of specific type of humidifier with manufacturers.

A. Direct-steam-injection humidifiers are specified in Section 238413.23 "Direct-Steam-Injection Humidifiers."

B. Self-contained humidifiers are specified in Section 238413.29 "Self-Contained Humidifiers."

C. Heat-exchanger humidifiers are specified in Section 238413.36 "Heat Exchanger Humidifiers."

2.11 AIR-TO-AIR ENERGY RECOVERY

Retain this article to require that air-to-air energy recovery units be provided by air-handling unit manufacturer; delete if air-to-air energy recovery units are specified in Section 237213 "Heat-Wheel Air-to-Air Energy Recovery Equipment," Section 237216 "Heat-Pipe Air-to-Air Energy Recovery Units," and Section 237219 "Fixed-Plate Air-to-Air Energy Recovery Units." Not all manufacturers offer energy recovery options; consult manufacturers.

A. Heat Wheels:

1. Casing:

    a. Galvanized steel, stainless steel, or aluminum with manufacturer's standard finish.
    b. Integral purge section limiting carryover of exhaust air to between [**0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg**] <**Insert values**> differential pressure.
    c. Casing seals on periphery of rotor, on duct divider, and on purge section.

d. Support rotor on grease-lubricated ball bearings with extended grease fittings. Mount horizontal wheels on tapered roller bearing.

Retain one of first two "Rotor" subparagraphs below. Not all manufacturers offer each combination of materials and coatings. Consult manufacturers.

2. Rotor: Aluminum or polymer segmented wheel, strengthened with radial spokes[**, with nontoxic, noncorrosive, silica-gel desiccant coating**].
3. Rotor: Aluminum, metallic, or polymer segmented wheel, strengthened with radial spokes impregnated with nonmigrating, water-selective, 3-angstrom molecular-sieve desiccant coating.
4. Drive: Fractional horsepower motor and gear reducer[**, with speed changed by variable-frequency controller**]. Permanently lubricated wheel bearings with an [**L-10**] <**Insert bearing life**> [**400,000 hours**] <**Insert hours**>.

Retain subparagraph below to require that controls be an integral part of air-handling unit; delete if controls are specified in Section 230923 "Direct Digital Control System for HVAC."

5. Controls:

   a. Starting relay, factory mounted and wired, and manual motor starter for field wiring.

Retain one of first three subparagraphs below.

   b. Variable-frequency controller, factory mounted and wired, permitting input of field connected 4- to 20-mA or 1- to 10-V control signal.
   c. Variable-frequency controller, factory mounted and wired, with exhaust-air sensor to vary rotor speed and maintain exhaust temperature above freezing.
   d. Variable-frequency controller, factory mounted and wired, with exhaust- and outdoor-air sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and maintain [**exhaust temperature above freezing and**]air differential temperature above set point. Provide maximum rotor speed when exhaust-air temperature is less than outdoor-air temperature.
   e. Pilot-Light Indicator: Display rotor rotation and speed.
   f. Speed Settings: Adjustable settings for maximum and minimum rotor speed limits.

B. Fixed-Plate Sensible Heat Exchangers:

1. Casing: [**Aluminum**] [**Galvanized steel**] <**Insert material**>.
2. Plates: Evenly spaced and sealed and arranged for [**counter**] [**cross**] airflow.
3. Plate Material: [**Embossed aluminum**] [**Stainless steel**] [**High-density plastic**].

Coatings are available for aluminum plates in corrosive atmospheres.

4. Plate Coating: [**Epoxy**] <**Insert coating**>.
5. Bypass: Plenum within casing, with gasketed face-and-bypass dampers that have operating rods extended outside casing.
6. Heat-Exchanger Prefilters: [**1 inch thick, disposable**] [**2 inches thick, disposable**] <**Insert type**> [**MERV 6**] <**Insert MERV**>.

2.12 AIR BLENDERS

Not all manufacturers offer air blenders or each material option; consult manufacturers.

A. Description: Static air mixer device to provide mixing of two airstreams to within [**plus/minus 6 deg F**] <**Insert mixing differential**>.

B. Material: [**Galvanized steel**] [**Aluminum**] <**Insert material**>.

C. Coating: [**None**] [**Corrosion-resistant coating**].

2.13 DIFFUSERS

Retain this article if specifying Type DWDI centrifugal fans. Delete if specifying plenum fans.

Not all manufacturers offer diffusers or each material option; consult manufacturers.

A. Description: Velocity profile equalizer device for providing equalized airflow profile downstream of Type DWDI fans.

B. Material: [**Galvanized steel**] [**Aluminum**] <**Insert material**>.

2.14 UV-C LAMP SYSTEMS

Not all manufacturers offer UV-C lamp systems as a factory-installed option; consult manufacturers.

A. Description:

1. UV-C lamp system consisting of power supply, power supply housing, wiring, UV lamp(s), lamp plug, lamp plug protector, encapsulated lamp, and lamp holder used for UV germicidal irradiation of cooling coil and condensate drain pan.
2. Factory installed and preengineered.

B. Standard: UL Category Code ABQK, HVAC accessories, air-duct mounted.

C. Lamps: High output, hot cathode.

D. Lamp-Holder Construction:

1. UV- and moisture-resistant materials and designed to connect the lamp to the plug.
2. Adjustable positioning.

E. Lamp-Clamp Construction:

1. UV- and moisture-resistant materials, water-tight connection.
2. Adjustable positioning.

F. Lamp Protection: Hermetically sealed to provide protection against lamp breakage and to ensure lamp contents from a broken lamp are contained.

G. Lamp Output: UV-C energy, primarily at the 254-nm wavelength with a 360-degree energy distribution.

H. Access Door Interlocks: Automatic disconnect on all access doors into UV-installed casing sections to shield servicing personnel from contact with light.

I. Power Supply: UL-listed, single-point electrical connection[**with service disconnect**].

J. Power Consumption: Maximum of [**15 W/sq. ft.**] <**Insert value**>.

2.15 MATERIALS

A. Steel:

1. ASTM A36/A36M for carbon structural steel.
2. ASTM A568/A568M for steel sheet.

B. Stainless Steel:

1. Manufacturer's standard grade for casing.
2. Manufacturer's standard type, ASTM A240/A240M for bare steel exposed to airstream or moisture.

C. Galvanized Steel: ASTM A653/A653M.

D. Aluminum: ASTM B 09.

Retain first paragraph below if corrosion-resistant coating is specified in Section 230546 "Coatings for HVAC." Retain "Corrosion-Resistant Coating" Paragraph if corrosion-resistant coating options are cited in "Preheat Coils," "Heating Coils," or "Cooling Coils" Paragraph and if corrosion-resistant coating is specified in this Section. Determine availability with air-handling unit manufacturers.

E. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating.

F. Corrosion-Resistant Coating: Coat with a corrosion-resistant coating capable of withstanding a [**3000**] <**Insert time**>-hour salt-spray test according to ASTM B117.

1. Standards:

   a. ASTM B117 for salt spray.
   b. ASTM D2794 for minimum impact resistance of 100 in-lb.
   c. ASTM B3359 for cross hatch adhesion of 5B.

2. Application: [**Immersion**] [**Spray**].
3. Thickness: [**1 mil**] <**Insert value**>.
4. Gloss: Minimum gloss of 60 on a 60-degree meter.

2.16 SOURCE QUALITY CONTROL

The majority of listed manufacturers are AHRI 430 certified, but a few are not. Consult manufacturers. Note that AHRI 430 requires fan performance to be in compliance with AMCA 210.

A. AHRI 430 Certification: Air-handling units and their components shall be factory tested according to AHRI 430 and shall be listed and labeled by AHRI.

Retain "AHRI 1060 Certification" Paragraph below if retaining "Air-to-Air Energy Recovery" Article and if AHRI certification is desired. Not all manufacturers offer energy recovery options and not all offer this certification. Consult manufacturers.

B. AHRI 1060 Certification: Air-handling units that include air-to-air energy recovery devices shall be factory tested according to AHRI 1060 and shall be listed and labeled by AHRI.

Retain "AMCA 301 or AHRI 260" Paragraph below when specifying maximum sound levels.

C. AMCA 301 or AHRI 260: Air-handling unit fan sound ratings shall comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data," or AHRI 260, "Sound Rating of Ducted Air Moving and Conditioning Equipment."

D. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.

E. Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."

F. Water Coils: Factory tested to 300 psig according to AHRI 410 and ASHRAE 33.

G. Steam Coils: Factory tested to 300 and 200 psig underwater according to AHRI 410 and ASHRAE 33.

H. Refrigerant Coils: Factory tested to minimum 450-psig internal pressure and to minimum 300-psig internal pressure while underwater, according to AHRI 410 and ASHRAE 33.

I. Witnessed Casing Leakage Tests:

1. Pay for all expenses, for one representative designated by Owner, to travel to the factory to witness cabinet air-leakage testing on the specific assembled unit(s) prior to release for delivery to Project site.
2. If the unit(s) does not meet specified leakage requirements, perform factory modifications and retest. Do not release unit for shipment until tested leakage is measured to be within specified leakage and leakage testing report has been accepted by Owner's designated representative.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for steam, hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

1. Install air-handling units on cast-in-place concrete equipment bases. Coordinate sizes and locations of concrete bases with actual equipment provided. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

Retain one of two subparagraphs below. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device types and minimum deflection in supported equipment schedule on Drawings.

2. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

B. Suspended Units: Suspend[**and brace**] units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]

C. Arrange installation of units to provide access space around air-handling units for service and maintenance.

Sustainable design systems require filters with a minimum MERV 13 rating for the air delivered to the occupied space. Air-handling units should not be used for temporary heating and ventilating unless expressly approved by Owner. If used during construction, see SMACNA's "IAQ Guidelines for Occupied Buildings under Construction" for procedures to protect HVAC system.

D. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.

E. Install filter-gauge, static-pressure taps upstream and downstream of filters. Mount filter gauges on outside of filter housing or filter plenum in accessible position. Provide filter gauges on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

Coordinate duct installations and specialty arrangements with schematics on Drawings and with requirements specified in Section 233113 "Metal Ducts" and Section 233300 "Air Duct Accessories."

F. Connect duct to air-handling units with flexible connections. Comply with requirements in Section 233300 "Air Duct Accessories."

3.3 PIPING CONNECTIONS

Coordinate piping installations and specialty arrangements with Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to air-handling unit, allow for service and maintenance.

C. Connect piping to air-handling units mounted on vibration isolators with flexible connectors.

D. Connect condensate drain pans using [**NPS 1-1/4**] <**Insert pipe size**>, ASTM B88, Type M copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

E. Hot- and Chilled-Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.

F. Steam and Condensate Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Heating Piping Specialties." Install shutoff valve at steam supply connections, float and thermostatic trap, and union or flange at each coil return connection. Install gate valve and inlet strainer at supply connection of dry steam humidifiers, and inverted bucket steam trap to condensate return connection.

G. Refrigerant Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping." Install shutoff valve and union or flange at each supply and return connection.

3.4 ELECTRICAL CONNECTIONS

A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

C. Install electrical devices furnished by manufacturer, but not factory mounted, according to NFPA 70 and NECA 1.

D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

Retain one of two subparagraphs below. First subparagraph cross-references Section 260553 "Identification for Electrical Systems" and should be retained for consistent electrical identification. Second subparagraph is an abbreviated version of the product specified in Section 260553 "Identification for Electrical Systems."

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.5 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring according to Section 260523 "Control-Voltage Electrical Power Cables."

3.6 STARTUP SERVICE

A. [**Engage a factory-authorized service representative to perform**] [**Perform**] startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that zone dampers fully open and close for each zone.
7. Verify that face-and-bypass dampers provide full face flow.
8. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
9. Comb coil fins for parallel orientation.
10. Verify that proper thermal-overload protection is installed for electric coils.
11. Install new, clean filters.
12. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.[**Replace fan and motor pulleys as required to achieve design conditions.**]
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.7 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

C. Occupancy Adjustments: When requested within [**12**] <**Insert number**> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <**Insert number**> visits to Project during other-than-normal occupancy hours for this purpose.

3.8 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

3.9 FIELD QUALITY CONTROL

Retain one of first four paragraphs below. Retain first "Testing Agency" Paragraph below if Owner will hire an independent testing agency.

A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.

Retain "Testing Agency" Paragraph below to require Contractor to hire an independent testing agency.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections and retain option to require Contractor to arrange for the assistance of a factory-authorized service agent.

D. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:

1. Leak Test: After installation, fill water and steam coils with water, and test coils and connections for leaks.
2. Charge refrigerant coils with refrigerant and test for leaks.
3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

Retain one of first two subparagraphs below for HEPA filters. Second subparagraph is for critical applications per ASME AG-1.

4. HEPA Filters: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.
5. HEPA Filters: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter for air leaks according to ASME AG-1, pressure-decay method.
6. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

E. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

F. Prepare test and inspection reports.

3.10 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION 237313.16

SECTION 237313.19 - INDOOR, CUSTOM AIR-HANDLING UNITS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes indoor, custom air-handling units with capacities, characteristics, and configurations indicated on Drawings.

B. Related Requirements:

1. Section 237343.19 "Outdoor, Custom Air-Handling Units."

1.3 ACTION SUBMITTALS

A. Product Data: For each air-handling unit.

1. Product information organized to show compliance with each performance requirement of "Performance Requirements" Article.
2. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
3. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
4. Include unit dimensions and weight.
5. Include cabinet material, metal thickness, finishes, insulation, and accessories.
6. Fans:

a. Include certified fan-performance curves with system operating conditions indicated. For fans operating at variable speeds include curves in [**10**] <**Insert**

number> percent speed increments starting at design speed down to minimum speed.

b. Include fan-sound power ratings in all eight octave bands. Include inlet or outlet sound power levels to coincide with sound requirements indicated on Drawings.
c. Include fan construction and accessories. Submit sufficient information to show product compliance with requirements indicated.
d. Include dimensions and weight.
e. Include motor ratings, electrical characteristics, and motor accessories.

7. Vibration isolation product data with performance ratings. Uniquely identify and include information for each different isolator type and indicate for each air-handling unit where each isolator type is being used.
8. Include certified coil-performance ratings with system operating conditions indicated. Product data to include dimensions, dry and operating weight, volume of fluid contained, materials of construction, and performance ratings with system operating conditions indicated.
9. Casing insulation product data and performance ratings.
10. Access door and access panel product data and performance ratings.
11. Paint product data and performance ratings.
12. Electrical product data and performance ratings.
13. Metal grating product data and performance ratings.
14. Electric heater product data with performance ratings.
15. Steam humidifier product data with performance ratings.
16. Dampers product data, including housings, linkages, and operators with performance ratings.
17. Filters product data with performance characteristics.
18. Heat wheels product data with performance ratings.
19. Fixed plate heat exchangers product data with performance ratings.
20. Heat pipe heat exchangers product data with performance ratings.
21. Duct silencers product data with performance ratings.
22. Air blender product data with dimensions, weights, materials of construction, performance ratings, and installation requirements.
23. UV-C lamp systems product data with performance ratings.
24. <**Insert requirements**>.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for ASHRAE 62.1.>
2. <Double click to insert sustainable design text for ASHRAE 90.1.>
3. <Double click to insert sustainable design text for AHU filter performance.>
4. <Double click to insert sustainable design text for adhesives, mastics, and sealants submittals.>

C. Shop Drawings: For each type and configuration of indoor, custom air-handling unit.

1. Prepared by manufacturer's factory employees with review and sign-off by those individuals responsible for manufacturing the air-handling units.
2. Include plans, elevations, sections, and [**mounting**] [**attachment**] details.[**For air-handling units consisting of multiple levels, create drawings for each level showing interrelationship of levels superimposed.**]

3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, methods of field assembly, components, and location and size of each field connection.
4. Detail fabrication and assembly of indoor, custom air-handling units, as well as procedures and diagrams.
5. Indicate details of construction with materials description including applicable specified standards and material grades in sufficient detail for reviewers to evaluate point by point compliance with requirements indicated for each air-handling unit.
6. Use actual dimensions of internal equipment in preparing Shop Drawings. Identify mechanical equipment shown on Shop Drawings with equipment designations on Drawings.
7. Thickness and finish of all casing materials with cross references indicated where each is used. Uniquely identify and include information for each different casing construction.
8. Details for each unique casing joint and reinforcing. Indicate wall joints, wall to floor joints, wall to roof joints, floor joints, and roof joints.
9. Assembly details of base and casing for units consisting of multiple sections requiring field assembly.
10. Sizes and dimensioned locations of field connections for ductwork, piping, electrical, and controls.
11. Base and casing penetration and sealing details for factory-installed conduit.
12. Base and casing penetration and sealing details for factory-installed piping including coils[**and steam humidifiers**].
13. Details of casing connections to field-installed ductwork.
14. Size, shape, and layout of base members including localized support of internal components.
15. Base materials, thickness, finishes, lifting provisions, and mounting requirements. Uniquely identify and include information for each different base construction. Clearly indicate for each air-handling unit.
16. Recommended points of field attachment with dimensioned locations.
17. Size and location of each access door, including clearing opening size, with door swing indicated.
18. Size and location of each access panel with service equipment superimposed to show relationship of panel to internal equipment.
19. Drain pans and associated piping, with sizes and locations dimensioned, including relationship to internal equipment.
20. Floor drains and associated piping, with sizes and locations dimensioned, including relation to internal equipment.
21. Coil framework and support including enlarged details showing framework attachment to air-handling unit base, coil attachment to framework, and means for individual coil removal.
22. Mounting details of all internal components, such as fans, filters, and dampers.
23. Hoist rails layout for internal equipment showing size of members, attachments to structure, and serviced equipment superimposed to indicate relationships.
24. Size and location of catwalks, handrails, ladders, and safety cages including construction details and details of attachment to air-handling unit base.
25. Location of UV-C lamp systems, service clearances, and mounting details.
26. Location of receptacles, service lights, and switches.
27. Location of motor controllers and disconnect switches.
28. Size and location of junction boxes used for interface with field electrical power.

29. Point-to-point electrical power wiring diagrams including wire size, conduit size, motor controllers sizes, switch types and ratings, receptacle types and ratings, service light fixture types, and ratings.
30. Point-to-point control wiring diagrams including cable types and sizes, conduit sizes, and connected control devices.
31. Point-to-point control tubing diagrams including tubing types and sizes, conduit sizes, and connection controls devices.
32. Control panel drawings drawn to scale showing detailed internal layout.
33. Indicate code, operating, and maintenance clearances drawn to scale using dashed lines.
34. Indicate weights of internal components, weight of each separately shipped section, and air-handling unit total weight.
35. <**Insert requirements**>.

D. Comparison Schedule:

1. Submit a schedule to indicate performance of equipment scheduled on Drawings directly compared to performance of submitted equipment.
2. Clearly identify each line in schedule to indicate "Scheduled" where indicating performance scheduled on Drawings and "Submitted" where indicating performance of submitted equipment.
3. Organize schedule to first indicate performance scheduled on Drawings on one line followed by line directly below that indicates performance of submitted equipment.
4. Comparison schedule shall follow arrangement and organization of scheduled information indicated on Drawings.
5. Submitted equipment shall have a value for each scheduled value indicated.

E. Delegated-Design Submittal: For vibration isolation[**and seismic restraints**] indicated to comply with performance requirements and design criteria, including analysis data[**signed and sealed by the professional engineer responsible for their preparation**.

1. For seismic restraints indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

   a. Include design calculations for selecting seismic restraints.

2. <**Insert requirements**>.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, sections, and other details, or BIM model, drawn to scale, showing the items described in this Section and coordinated with all building trades.

B. Seismic Qualification Data: Certificates for air-handling units, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
4. Restraint of internal components.

C. Source quality-control reports.

D. Startup service reports.

E. Field quality-control reports.

F. Sample Warranty: For manufacturer's warranty.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Bag Filters: [**One**] <**Insert number**> set(s) for each air-handling unit.
2. Cartridge Filters: [**One**] <**Insert number**> set(s) for each air-handling unit.
3. Panel Filters: [**One**] <**Insert number**> set(s) for each air-handling unit.
4. Absolute Filters: [**One**] <**Insert number**> set(s) for each air-handling unit.
5. Gas-Phase Filters: [**One**] <**Insert number**> set(s) for each air-handling unit.
6. Access Door Gaskets: [**One**] <**Insert number**> set(s) for each [**unique**]access door.
7. Fan Belts: [**One**] <**Insert number**> set(s) for each fan with belt-drive assembly.
8. Heat Wheel Belts: [**One**] <**Insert number**> set(s) for each heat wheel with belt-drive assembly.

B. Tool Kit: Manufacturer to provide a tool kit including special tools required for air-handling unit service. See "Accessories" Article for additional requirements.

1.7 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

1.8 FACTORY VISITS FOR PRODUCT INSPECTION

A. While units are being manufactured, and during factory normal working hours, allow escorted access to manufacturing facility for [**Owner**] [**or**] [**and**] [**Owner's designated representative**] to verify product compliance with requirements indicated.

1. As many as <**Insert number**> persons shall visit factory for product inspection.

B. Manufacturer shall provide [**Owner**] [**and**] [**Architect**] with written notice at least [**30**] <**Insert number**> business days before units go into assembly.

C. Inspection visits shall be scheduled with manufacturer at least [**10**] <**Insert number**> business days before visit.

D. Personnel making visits for purposes of product inspection shall comply with manufacturer requirements for visitors.

1.9 DELIVERY, STORAGE, HANDLING

A. Deliver air-handling units with factory-installed shipping skids and lifting lugs; pack small components in factory-fabricated protective containers. Cover units with heat-shrinkable plastic sheeting suitable for shipping from point of manufacture to Project.

B. Handle air-handling units carefully to avoid damage to components, casing, and finish. Do not install damaged components; replace and return damaged components to air-handling unit manufacturer.

C. Store air-handling units in a clean dry place and protect them from weather and construction activities.

D. Keep air-handling units fully covered and protected during construction. Remove dirt and debris and clean units to a factory-cleaned condition.

E. Comply with manufacturer's written rigging and installation instructions for unloading air-handling units and moving them to their final locations.

F. For air-handling units equipped with key locks on access doors, keep doors locked during construction.

1. If access is required within air-handling units, only open the doors to sections that require access and lock doors at the end of each [**workday**] [**work shift**] <**Insert requirement**>.
2. Protect inside of air-handling units from damage and keep inside of units as clean as the factory-cleaned condition.
3. Report observed abuse to <**Insert entity**> for immediate corrective action.

1.10 WARRANTY

A. Warranty: Manufacturer agrees to repair or replace components of air-handling units that fails in materials or workmanship within specified warranty period.

1. Warranty Period: <**Insert number**> year(s) from date of Substantial Completion.

B. Extended warranties include, but are not limited to, the following:

1. Complete Air-Handling Unit: [**Two**] [**Three**] [**Five**] <**Insert number**> years from date of Substantial Completion for entire air-handling unit and longer where indicated for individual components.
2. Air-Handling Unit Casing: [**25**] [**30**] <**Insert number**> years from date of Substantial Completion.
3. Motors: [**Two**] [**Five**] <**Insert number**> years from date of Substantial Completion.
4. Heat Wheels: [**Five**] [**10**] <**Insert number**> years from date of Substantial Completion.
5. <**Insert requirement**>.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handing units and components.

C. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

E. Delegated Design: Engage a qualified professional [**specialist**] [**engineer**], as defined in Section 014000 "Quality Requirements," to design air-handling units, [**vibration isolation,**] [**and seismic restraints**] including comprehensive engineering analysis, using performance requirements and design criteria indicated.

F. Casing Structural Performance:

1. Floor: Capable of withstanding positive/negative [**8 inches wg**] <**Insert value**> of internal static pressure, without exceeding a deflection of [**L/300**] [**L/360**] <**Insert deflection**> of span.
2. Walls and Roof: Capable of withstanding positive/negative [**8 inches wg**] <**Insert value**> of internal static pressure, without exceeding a midpoint deflection of [**L/200**] [**L/240**] <**Insert deflection**> of span.

G. Casing Leakage Performance, ASHRAE 111: [**Class 3 leakage**] <**Insert leakage class**> or better at [**plus or minus 8 inches wg**] <**Insert pressure**>.

H. Casing Leakage Performance: Comply with more stringent of the following requirements:

1. ASHRAE 111, [**Class 3 leakage**] <**Insert leakage class**> or better at [**plus or minus 8 inches wg**] <**Insert pressure**>.
2. Not more than [**0.5**] <**Insert number**> percent of the total unit airflow at [**8 inches wg**] <**Insert pressure**>.

I. Casing Thermal Performance:

1. Surface Condensation: Air-handling manufacturer shall evaluate potential for condensation and design and manufacture entire unit casing to prevent condensation at most extreme operating conditions encountered.
2. Thermal Break: Incorporate a thermal break at each through metal path to prevent condensation from occurring on interior and exterior of casing.
3. U-Value: Overall U-value or equivalent R-value of casing shall not exceed governing codes and ASHRAE/IES 90.1, while considering the effects of metal-to-metal contact and thermal bridging in calculations.

J. Air Tunnel Aerodynamic Performance: Position air-handling unit internal components and transition between internal components to maintain uniform airflow; minimize sound levels and energy consumption. Use methods indicated and other means to ensure compliance.

1. Use turning vanes if necessary to direct the air path.

   a. Design, manufacture, and install vanes in accordance with applicable requirements in ASHRAE and SMACNA guidelines, handbooks, and standards.
   b. Install vanes firmly in place so that no vane movement occurs at worst-case airflow capacity possible.

2. Use fan inlet and discharge transitions and other devices to maximize system regain and minimize airborne sound levels.
3. Center system components such as coils, fans, and filters, vertically and horizontally, in airstream.
4. Maintain spacing between components such that airflow patterns to adjacent components are as uniform as possible and that component "dead spots" or "jetted areas" are avoided.
5. Design and install internal structural supports, piping, and conduit that do not block airflow and impede performance of coils, fans, filters, and other unit components, and service space clearances.

K. Air-Handling Unit Acoustical Performance:

1. Radiated Noise: Noise radiated from air-handling unit casing[**and openings not ducted**] shall not exceed following sound pressure levels when measured [**3 feet**] <**Insert distance**> away from any exterior surface of unit. Sound pressure levels indicated in each octave band are in decibels (dB) (reference 20 µPa).

   a. 63 Hz: <**Insert value**> dB.
   b. 125 Hz: <**Insert value**> dB.
   c. 250 Hz: <**Insert value**> dB.
   d. 500 Hz: <**Insert value**> dB.
   e. 1000 Hz: <**Insert value**> dB.
   f. 2000 Hz: <**Insert value**> dB.
   g. 4000 Hz: <**Insert value**> dB.

L. Casing Acoustical Performance:

1. Sound Absorption: Minimum acceptable sound absorption coefficient and noise reduction coefficient (NRC) of perforated inside casing assemblies when tested by an independent testing laboratory in accordance with ASTM C423 and ASTM E795.

   a. 125 Hz: <**Insert value**> dB.
   b. 250 Hz: <**Insert value**> dB.
   c. 500 Hz: <**Insert value**> dB.
   d. 1000 Hz: <**Insert value**> dB.
   e. 2000 Hz: <**Insert value**> dB.
   f. 4000 Hz: <**Insert value**> dB.
   g. NRC: <**Insert value**>.

2. Sound Transmission: Minimum acceptable sound transmission loss and STC of proposed cabinet construction when tested by an independent testing laboratory in accordance with ASTM E90 and ASTM E413.

   a. 125 Hz: <**Insert value**> dB.
   b. 250 Hz: <**Insert value**> dB.
   c. 500 Hz: <**Insert value**> dB.
   d. 1000 Hz: <**Insert value**> dB.
   e. 2000 Hz: <**Insert value**> dB.
   f. 4000 Hz: <**Insert value**> dB.
   g. STC: <**Insert value**>.

M. Durability Performance: Design and manufacture air-handling units with underlying requirement to provide a highly durable piece of equipment.

1. Unit Life Expectancy: [**25**] <**Insert number**> years.
2. Supporting Documentation: Submit documentation showing proposed products to consider and include design features, components, and materials to satisfy requirement.

N. Extreme Operating Conditions:

1. Corrosive Environments: Air-handling unit manufacturer shall evaluate the quality and potential corrosiveness of air passing through air-handling units and propose additional protective finishes and better-quality materials of a heavier thickness if required to comply with requirements indicated.

   a. Unless otherwise indicated, air-handling units for HVAC applications may use up to 100 percent of outdoor air or a mix of outdoor air with return air from habitable areas served.[**Projects located in coastal and industrial areas may require added protection.**]
   b. Air-handling units circulating [**Class 3**] [**and**] [**Class 4**] exhaust air in accordance with ASHRAE 62.1 could potentially be hot, humid, and corrosive and may require added protection.

2. Humidity and Temperatures: Materials and components of air-handling units shall be suitable for use in low and high humidity and temperature extremes when operating under normal and abnormal conditions without permanent degradation or loss in material performance.

O. Safety:

1. Comply with OSHA regulations.
2. Exposed sharp edges and corners of metal shall be protected or rounded to prevent injury to personnel not wearing gloves.
3. Cover exposed ends of screws with plastic or metal covers to prevent injury to personnel coming in contact with screws.

P. Serviceability:

1. Hoisting Provisions: Fans and motors weighing more than [**200 lb**] <**Insert weight**> to have full-length hoist rails mounted over the equipment to facilitate service, removal, and replacement.
2. Mounting Location: Install internal components in readily accessible locations to facilitate ease of service and replacement.
3. Service Access:

   a. Internal components shall be serviceable through access sections with doors indicated on Drawings.
   b. Internal components shall be removable and replaceable through access doors or panels.
   c. Review requirements for access doors and panels indicated and recommend additional access doors and panels if required for uninhabited service, removal, and replacement of components.

4. Tripping Hazards: Floors in accessible sections of air-handling unit shall be free of standing seams, reinforcing, supports, or section splits located in the walking path that is capable of causing a tripping hazard. Locate section splits immediately adjacent to internal walls.

Q. Quality: Type and thickness of materials indicated are the minimum acceptable. Provide better-quality materials of a heavier thickness if required to comply with performance requirements indicated.

1. If manufacturer's standard construction exceeds requirements indicated, use manufacturer's standard construction.
2. If manufacturer's standard construction does not comply with requirements indicated, modify manufacturer's standard construction to comply with requirements.

R. Seismic Performance: Air-handling units shall withstand the effects of earthquake motions determined in accordance with [**ASCE/SEI 7**] <**Insert requirement**>.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."
2. Component Importance Factor: [**1.5**] [**1.0**].
3. <**Insert requirements for Component Amplification Factor and Component Response Modification Factor**>.

S. Vibration Performance: Air-handling unit manufacturer shall evaluate vibration of internal components installed inside of air-handling units and include internal vibration isolation required to limit the vibration transmitted to the building at a low enough level that vibration is not perceived by building occupants.

2.2 CAPACITIES AND CHARACTERISTICS

A. See equipment schedules on Drawings.

2.3 SOURCE LIMITATIONS

A. Source all indoor [**and outdoor**]custom air-handling units from same manufacturer.

B. Like components furnished with air-handling units shall be from same manufacturer.

C. Air-handling units shall be manufactured in [**United States**] [**United States or Canada**] [**North America**] <**Insert requirement**>.

D. <**Insert requirements**>.

2.4 MANUFACTURERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.5 UNIT ARRANGEMENT AND CONFIGURATION

A. Arrangement: Project-specific arrangement and configuration of air-handling units as indicated on Drawings. Do not deviate from requirements indicated[**without submitting a formal request clearly describing each deviation and reason for each deviation, and only after receiving Architect's written acceptance**].

B. Mounting Requirements: [**Indicated on Drawings**] [**Units mounted on concrete housekeeping pads**] [**Units mounted on structural floor**] [**Units mounted on structural-steel frame**] [**Units suspended from structure**].

C. Multiple Sections: Each air-handling unit shall consist of multiple sections for field assembly to comply with requirements indicated on Drawings.

D. Multiple Sections, Splits: Air-handling unit manufacturer to determine number of sections and location of section splits required for each air-handling unit in accordance with the following criteria:

1. Physical size and weight of each section, on-site path of travel, and methods for erection and installation. Air-handling manufacturer to review criteria with Installer before preparing Shop Drawings.
2. Maximize physical size of each air-handling unit section considering, shipping, moving, erecting, and installation.
3. Limit physical size to fit within available building openings without altering building construction.

4. Minimize the number of air-handling unit sections requiring field assembly. Preference is for single-piece air-handling units where possible.

E. Knock-Down Construction: Physical limitations of existing building(s) require a specialized installation consisting of field assembly of air-handling unit kit of parts shipped on pallets or in containers. Before preparing Shop Drawings, air-handling unit manufacturer shall review with Installer the on-site path of travel, physical size of each opening, weight limits, and methods for erection and installation.

2.6 AIR-HANDLING UNIT BASE

A. Performance:

1. Air-handling unit manufacturer shall design and assemble air-handing unit casing and internal components for attachment and support by air-handling unit structural base.
2. Design air-handling units to be lifted from only the air-handling unit structural base and not the casing.
3. Support air-handling units from only the perimeter base unless otherwise indicated on Drawings.
4. Air-handling unit manufacturer to size and locate intermediate structural base supports as required to comply with structural performance indicated for air-handling unit floors.
5. Level base before factory assembly of air-handling unit casing and internal components to ensure proper fit and alignment.

B. Structural Member Size:

1. Air-handling unit manufacturer shall select size of base members and construction of base to withstand the rigors of loading, unloading, shipping, and rigging without damage to air-handling unit components or misalignment of factory-assembled components.
2. Depth and weight of structural members shall be selected by air-handling unit manufacturer to comply with performance requirements indicated.
3. Depth of perimeter base members is not less than [**size indicated on Drawings**] [**1/10 of the unit width**] [**8 inches deep**] <**Insert requirement**>.

C. Structural Member Spacing: Positioned as required to comply with requirements indicated, but not to exceed [**24 inches**] <**Insert requirement**>.

D. Materials: [**Structural aluminum, ASTM B209, Alloy 6061 T6**] [**structural carbon steel, ASTM A36/A36M**] [**structural stainless steel, ASTM A276/A276M, Type 304L**] [**or**] [**structural stainless steel, ASTM A276/A276M, Type 316L**] [**as indicated on Drawings**].

1. Perimeter Members: [**Angle**] [**channel**] [**I or W beam shapes**] [**or**] [**tube**].
2. Intermediate Members (Spanning Full Width of Unit): [**Angle**] [**channel**] [**or**] [**I or W beam shapes**] [**or**] [**tube**].
3. Cross Members (Spanning Intermediate Members): [**Angle**] [**channel**] [**or**] [**tube**].

E. Carbon-Steel Finish, Mill Galvanized: Mill-galvanized carbon steel with weld-damaged areas cleaned, prepared, and painted with galvanized paint after fabrication.

F. Carbon-Steel Finish: Carbon-steel bases shall be shot-blasted, cleaned, prepared, and [**painted**] [**or**] [**hot-dip galvanized**] after fabrication.

G. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.

1. Use welding materials with corrosion properties equal to material being welded.

H. Welding Procedures:

1. Structural Welding Codes: [**AWS D1.1/D1.1M for carbon steel**] [**AWS D1.2/D1.2M for aluminum**] [**AWS D1.6/D1.6M for stainless steel**].
2. Join structural members to one another using [**continuous**] [**or**] [**stitch**] welds.
3. After welding and fabrication, deburr and grind exposed welds to provide smooth surfaces free of sharp edges.

I. Penetrations through Base Perimeter: Seal [**weld**]pipe, tubing, and conduit penetrations through base perimeter members to provide a watertight assembly.

J. Section Joints: Air-handling units consisting of multiple sections for field assembly shall be joined with structural joining plates.

1. Joining plate material type to match base.
2. Joining plate of thickness required to join sections without resulting in a permanent deflection, minimum [**1/2 inch**] <**Insert dimension**> thick.
3. Continuously weld joining plates to each mating end of base.
4. Joining plates shall not extend beyond outer edge of adjoining base.
5. Plates to include at least three equally spaced holes for field connection using factory-furnished threaded hardware of a nominal diameter of at least [**1/2 inch**] <**Insert diameter**>.

K. Lifting Provisions: Air-handling unit manufacturer to design and install lifting lugs of size and location required to comply with performance requirements indicated.[**Lifting lugs extending beyond the base shall be easily removable in the field after unit is installed.**]

2.7 UNIT CASINGS

A. Casing Assembly:

1. Appearance:

   a. Exposed exterior surfaces of casing shall have a neat and finished appearance free of standing seams, exposed reinforcing, and other casing protrusions more than [**0.25 inch**] [**0.5 inch**] <**Insert dimension**> beyond the exterior skin surface.
   b. Underside of air-handling units with finished installation exposed to view shall have finished appearance matching casing walls. Casing shall be recessed within the perimeter structural base to provide a single contiguous plane.
   c. Interior surfaces of casing shall have a neat and finished appearance free of standing seams, exposed reinforcing, and other casing protrusions more than [**0.25 inch**] [**0.5 inch**] <**Insert dimension**> beyond the skin surface.

2. Dissimilar Metals: Isolate dissimilar metals that are in contact to prevent galvanic action and corrosion.
3. Framing and Supports: Interconnect and support individual casing wall and roof panels using either formed panel construction or framed construction with structural support members. For framed casing construction, materials used to construct casing of structural support members shall be as follows:

    a. Casings with Aluminum Outer and Inner Skins: Aluminum extrusions in accordance with ASTM B211, Alloy 6063 T6.
    b. Casings with Galvanized-Steel Outer and Inner Skins: Galvanized steel.
    c. Casings with Galvanized-Steel Outer Skin and Aluminum or Stainless Steel Inner Skins: Stainless steel.
    d. Casings with Stainless Steel Outer and Inner Skins: Stainless steel.

4. Seals: Seal interior and exterior joints and seams to make casing air- and watertight. Trim factory-applied sealant flush with adjacent surface.
5. Double-Wall Casings: Consisting of insulation sandwiched between an outer and inner metal wall. Use double-wall casings to construct air-handling units unless septum casings are required.
6. Septum Casings: Triple-wall construction consisting of a solid metal inner wall sandwiched between insulation layers that are covered with metal walls. Use septum casings for applications having performance requirements that are not achievable with double-wall casings.
7. Penetrations: Seal voids around conduit, piping, and tubing penetrations.

        1) Walls and Roofs:

        2) Conduit, Pipe, and Tube Sizes [NPS 3] <Insert pipe size> and Smaller:

            a) Seal void through casing with a nonhardening vapor-barrier caulk covered by an escutcheon on both interior and exterior sides of casing. Back caulk using formed insulation within a sheet metal sleeve.
            b) Seal void using a friction fit neoprene or EPDM sheet material attached to casing using a bed of adhesive.
            c) Cover penetration and sealing sheet material with metal escutcheon matching adjacent casing material.

        3) Larger Conduit, Pipe, and Tube Sizes: Seal annular void using an adjustable compression-type sealing sleeve.

        4) Floors: Route conduit, pipe, and tube within a floor-mounted pipe sleeve.

        5) Sleeve:

            a) Fabricate sleeve of aluminum[**, galvanized-steel,**] or stainless steel pipe.
            b) Extend top of sleeve above adjacent floor surface to prevent standing water on floor from entering annular space of sleeve.
            c) Seal[weld] sleeve to top of floor for an air- and watertight seal.

6) Seal annular void of sleeve using an adjustable compression seal [**or**] [**nonhardening packing material**].

8. Floor Openings with Metal Grating:

a. Factory install walk-on safety gratings over any floor opening large enough to create a safety hazard for operators including, but not be limited to, supply-, return-, and exhaust-air openings.
b. Bar Grating:

1) Materials: Use [**stainless steel grating for aluminum**] [**stainless steel grating for stainless steel**] [**hot-dip galvanized-steel grating for galvanized-steel**] [**painted steel grating for painted steel**] floors.
2) Air-handling unit manufacturer shall select depth and thickness of grating bars to limit deflection to 1/360 of span when subjected to a dynamic load of not less than [**500 lb**] <**Insert weight**>.
3) Industry-standard welded grating with bars at least 1-1/2 inches deep by at least 3/16 inch thick with nominal 1-3/16-inch main bar spacing and 4-inch cross bar spacing.
4) Source: Product manufacturer specializing in metal gratings.
5) Grating bearing surface shall extend beyond clear opening in floor at least [**2 inches**] [**3 inches**] <**Insert dimension**>.

c. Mounting Frame:

1) Mount grating in a continuous structural angle or bar frame so no ends of grating bars are exposed. Top of frame to be flush with top of grating.
2) Secure grating to frame with threaded hardware, so grating does not move when walked on but can be easily removed from top to gain access behind grating.
3) Continuously weld mounting frame to air-handling unit floor.
4) Fasten mounting frame to air-handling unit floor with hardware and seal attachment air- and watertight.
5) For applications with automatic dampers installed at floor openings, elevate height of mounting frame and grating to enclose entire damper assembly including jackshaft so walk-on surface of grating is above damper assembly.

9. Waterproof Floors: Continuously weld floor joints, seams, and penetrations to completely seal floor. Roll all edges of floor up at least [**1 inch**] <**Insert dimension**> to create a shallow tub capable of holding standing water.
10. Duct Connections - Direct to Casing: Frame and reinforce unit casing around perimeter of unit duct openings to accommodate direct attachment of field-installed ductwork. Coordinate requirements with Installer to accommodate field connection.
11. Duct Connections - Elevated Off Casing:

a. Terminate with angle flange face elevated [**3 inches**] <**Insert dimension**> from exterior surface of casing.
b. Flange Thickness: [**0.25 inch**] <**Insert dimension**>.
c. Flange face with holes located not more than [**4 inches**] <**Insert dimension**> o.c., starting at corners, and sized for [**0.375-inch-**] diameter, field-installed hardware.
d. Size flange face to mate to full face of duct flange.

1) Clear inside dimension of unit connection to match clear inside dimension of duct.
2) For connections to acoustically lined ducts, increase unit flange face to accommodate thickness of liner so end of duct liner is concealed by air-handling unit flange.

12. <**Insert requirements**>.

B. Materials for Outer Skin of Casing Walls and Roofs:

1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; [**G90**] <**Insert coating**> coating; minimum (nominal) [**18 gauge**] [**16 gauge**] [**14 gauge**] <**Insert value**> thick.
2. Aluminum Solid Sheet: ASTM B209; Alloy 3003-H14, [**smooth**] [**stucco-embossed texture**] [**or**] [**leather-grain texture**] <**Insert finish**> finish; minimum (nominal) [**0.063 inch**] [**0.080 inch**] <**Insert value**> thick.
3. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M, [**Type 304**] [**Type 304L**] [**Type 316**] [**Type 316L**] <**Insert type**>; No. [**2D**] [**or**] [**4**] <**Insert finish**> finish; minimum (nominal) [**18 gauge**] [**16 gauge**] [**14 gauge**] <**Insert value**> thick.
4. Application: See Drawings for application of different materials indicated.

C. Materials for Inner Skin of Casing Walls and Roofs:

1. Galvanized-Steel Solid[**and Perforated**] Sheet: ASTM A653/A653M; [**G90**] <**Insert coating**> coating, minimum (nominal) [**20 gauge**] [**18 gauge**] [**16 gauge**] <**Insert value**> thick.
2. Aluminum Solid[**and Perforated**] Sheet: ASTM B209; Alloy 3003-H14, [**smooth**] <**Insert finish**> finish; minimum (nominal) [**0.032 inch**] [**0.040 inch**] [**0.063 inch**] [**0.080 inch**] <**Insert value**> thick.
3. Stainless Steel Solid[**and Perforated**] Sheet: ASTM A240/A240M or ASTM A480/A480M; [**Type 304**] [**Type 304L**] [**Type 316**] [**Type 316L**] <**Insert type**>; No. [**2D**] <**Insert finish**> finish; minimum (nominal) [**20 gauge**] [**18 gauge**] [**16 gauge**] <**Insert value**> thick.
4. Application: See Drawings for application of different materials indicated.

D. Materials for Floor Walking Surface:

1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; [**G90**] <**Insert coating**> coating; minimum (nominal) [**14 gauge**] [**12 gauge**] [**10 gauge**] <**Insert value**> thick.
2. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M, [**Type 304**] [**Type 304L**] [**Type 316**] [**Type 316L**] <**Insert type**>; No. [**2D**] <**Insert finish**> finish; minimum (nominal) [**14 gauge**] [**12 gauge**] [**10 gauge**] <**Insert value**> thick.
3. Carbon-Steel Diamond Treadplate: ASTM A786/A786M, painted finish; minimum (nominal) [**0.125 inch**] [**0.1875 inch**] <**Insert value**> thick.
4. Aluminum Diamond Treadplate: ASTM B632/B632M, Alloy 6061 T6; mill finish; minimum (nominal) [**0.125 inch**] [**0.1875 inch**] <**Insert value**> thick.
5. Stainless Steel Diamond Treadplate: ASTM A793; [**Type 304**] [**Type 304L**] [**Type 316**] [**Type 316L**] <**Insert type**>; mill finish; minimum (nominal) [**0.125 inch**] [**0.1875 inch**] <**Insert value**> thick.
6. Application: See drawings for application of different materials indicated.

E. Materials for Underside of Floor Insulation:

1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; [**G90**] <**Insert coating**> coating, minimum (nominal) [**18 gauge**] [**16 gauge**] <**Insert value**> thick.
2. Aluminum Solid Sheet: ASTM B209; Alloy 3003-H14, [**smooth**] <**Insert finish**> finish; minimum (nominal) [**0.040 inch**] [**0.063 inch**] [**0.080 inch**] <**Insert value**> thick.
3. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M; [**Type 304**] [**Type 304L**] [**Type 316**] [**Type 316L**] <**Insert type**>; No. [**2D**] [**4**] <**Insert finish**> finish; minimum (nominal) [**18 gauge**] [**16 gauge**] <**Insert value**> thick.
4. Application: See Drawings for application of different materials indicated.

F. Materials for Internal Walls:

1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; [**G90**] <**Insert coating**> coating; minimum (nominal) [**16 gauge**] [**14 gauge**] <**Insert value**> thick.
2. Aluminum Solid Sheet: ASTM B209; Alloy 3003-H14, smooth finish; minimum (nominal) [**0.063 inch**] [**0.080 inch**] <**Insert value**> thick.
3. Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M, [**Type 304**] [**Type 304L**] [**Type 316**] [**Type 316L**] <**Insert type**>; No. 2D finish; minimum (nominal) [**16 gauge**] [**14 gauge**] <**Insert value**> thick.
4. Application: See Drawings for application of different materials indicated.

G. Surfaces in Contact with Airstream:

1. Comply with ASHRAE 62.1 and NFPA 90A.
2. Glass or mineral-fiber insulation installed behind perforated metal shall be encapsulated to prevent insulation fibers from entering the airstream by using a [**polymer sheet material**] [**or**] [**tightly woven glass cloth material that does not impact the acoustical absorption properties of insulation**].

H. Insulation for Casing Walls and Roofs Not Exposed to Airstream:

1. Materials Not Exposed to Airstream: [**Glass or mineral-fiber board**] [**injected or sprayed polyurethane foam**] [**or**] [**polyurethane foam board**] insulation with a minimum nominal density of [**2 lb/cu. ft.**] [**3 lb/cu. ft.**] <**Insert density**>.
2. R-Value: Minimum [**R-8**] [**R-10**] [**R-12**] [**R-16**] <**Insert value**>.
3. Thickness: Minimum [2 inches] [**2.5 inches**] [**3 inches**] [**4 inches**] <**Insert dimension**>.
4. Insulation shall completely fill the casing cavity so no voids exist.

I. Insulation for Casing Walls and Roofs Exposed to Airstream:

1. Materials Exposed to Airstream: Glass or mineral-fiber board insulation with a minimum density of [**2 lb/cu. ft.**] [**3 lb/cu. ft.**] [**6 lb/cu. ft.**] <**Insert density**>.
2. R-Value: Minimum [**R-8**] [**R-10**] [**R-12**] [**R-16**] <**Insert value**>.
3. Thickness: Minimum [2 inches] [**2.5 inches**] [**3 inches**] [**4 inches**] <**Insert dimension**>.
4. Insulation shall completely fill the casing cavity so no voids exist.

J. Insulation for Casing Floors:

1. Materials: [**Glass or mineral-fiber board insulation**] [**injected or sprayed polyurethane foam**] [**or**] [**polyurethane foam board**] insulation with a minimum nominal density of [**2 lb/cu. ft.**] [**3 lb/cu. ft.**] <**Insert density**>.
2. R-Value: Minimum [**R-8**] [**R-10**] [**R-12**] [**R-16**] <**Insert value**>.

3. Thickness: Minimum [2 inches] [**2.5 inches**] [**3 inches**] [**4 inches**] <**Insert dimension**>.
4. Insulation shall completely fill the casing cavity so no voids exist.

K. Access Doors:

1. Application: [**Install access doors in air-handling units at locations indicated on Drawings**] [**Install access doors downstream and upstream of all internal components**] <**Insert requirement**>.
2. Adjustment: Design doors for field adjustment capable of maintaining specified leakage rate.
3. Mounting Height: Install bottom of door frame within [**2 inches**] <**Insert dimension**> of air-handling unit floor walking surface.[**Where internal conditions require access doors to be mounted higher above air-handling unit floor, include permanent retractable stairs inside and outside of air-handling unit to limit stair risers to 6 inches.**]
4. Performance: Leakage as required to satisfy overall unit leakage performance indicated, but not more than [**1.0 cfm**] <**Insert leakage rate**> per door when tested at 10 inch wg.
5. Fabrication: Formed and reinforced, constructed of same materials and thicknesses as casing.[**Where doors are installed in casing walls with perforated interior, install doors with solid interior.**]
6. Swing: Arrange doors to be opened against pressure unless otherwise indicated on Drawings.
7. Frame: [**Extruded aluminum with thermal break**] [**galvanized steel**] [**or**] [**stainless steel**] with [**welded**]mitered corners.
8. Handles:

   a. Secure door closed using not less than two [**roller-style**]latches with handles located at quarter points along door height.
   b. If three latches with handles are included, install one at midpoint of door height and equally space others.
   c. Air-handling unit manufacturer has option to use a multipoint latching mechanism that is operable from a single door handle located at midpoint of door height, but secures door to frame at top, bottom, and handle location.
   d. Include door handles on outside and inside of door to allow operator access to open and close door from outside and inside of unit.
   e. Field adjustable to accommodate changes to fit and gasket compression.
   f. Durable product capable of withstanding repeated opening and closing of door while operating under design pressure without damage.

9. Hinges: [**Minimum of two hinges**] [**minimum of three hinges**] [**or**] [**full-length, concealed, stainless steel piano hinge**].
10. Gasket:

   a. Design: Specially formed with an internal air chamber specifically designed to seal on two surfaces without taking a permanent set.
   b. Dual Gaskets: Primary and secondary gasket.
   c. Location: Install gaskets around entire perimeter of doors or frames.
   d. Material: EPDM, neoprene, or santoprene.
   e. Protection: Seat gasket in a protective metal ribbed chamber integral to door or door frame to protect gasket from damage by operator incidental contact.
   f. Service: Field replaceable.

g. Adhesive-backed tape-type gaskets adhered to a single flat surface are unacceptable.

11. Size of Door Frame Clear Opening: Large enough to allow for unobstructed access for inspection and maintenance of air-handling unit's internal components.

a. Width: At least [**18 inches**] [**24 inches**] <**Insert dimension**> clear inside of door frame.
b. Height: Full clear height of unit casing up to a maximum height of [**60 inches**] [**72 inches**] <**Insert dimension**> clear inside of door frame.
c. Door sizes indicated on Drawings.

12. Safety Latches and Stops:

a. Safety Latches: Install safety latch with retainers on outward swing doors that do not open against pressure to allow restricted travel for purpose of pressure relief and so that doors do not open uncontrollably due to inside pressure.
b. Stops: Install cushioned door stops on inward swinging doors where necessary to limit door travel that could potentially damage the door or internal components.

13. Tie-Backs: Install tie-backs with retainers on[**outward-swinging**] access doors to hold doors in an open position during service.
14. Locks: Include each access door with an integral key lock. Pad locks are unacceptable.

a. Incorporate key lock into door handle where feature is available.
b. A common key shall be used to lock and unlock access doors of [**each**] [**all**] air-handling unit(s).
c. Include [**two**] <**Insert value**> keys[**for each air-handling unit**].
d. Lock access doors at factory to ensure that unauthorized access is in place before air-handling unit packaging and shipment.

15. Windows:

a. Construction: Fabricate windows with frame mounted in access doors of double-glazed safety glass with an airspace between panes and interior and exterior seals.
b. Condensation Control: Install desiccant material in airspace between panes if necessary to prevent condensation from forming on glazing.
c. Clear Viewing Size: Minimum [**6 inches**] [**8 inches**] [**12 inches**] <**Insert dimension**>, square[**or round**].
d. Mounting Location: Center window in door width. For doors up to [**60 inches**] <**Insert dimension**> high, locate top of window [**6 inches**] <**Insert dimension**> below top of door. For taller doors, locate center of windows at optimal viewing height, approximately [**60 inches**] <**Insert dimension**> above floor adjacent to unit.
e. Application: Install windows in [**all access doors**] [**only access doors servicing fans**] [**only access doors servicing fans and filters**] [**only access doors servicing coils, dampers, heat wheels, fans, filters, and UV-C lamps**] <**Insert requirement**>.

16. Nameplates:

a. On each access door, include a nameplate defining the access to service within. Nameplates shall be included for, but not be limited to, the following:

1) Dampers.
2) Filters.
3) Gas-Phase Filters.
4) Cooling Coils.
5) Heating Coils.
6) Electric Heaters.
7) Duct Silencers.
8) Heat Wheels.
9) Fixed Plate Exchangers.
10) Heat Pipe Heat Exchangers.
11) UV-C Lamp Systems.
12) Supply Fans.
13) Exhaust Fans.
14) Return Fans.
15) Humidifiers.
16) Air Blenders.
17) <**Insert items**>.
18) Air-handling unit designation.
19) Where door access is to multiple components, list all components accessed. For example: Filter/Cooling Coil.
20) For each door that does not open against static pressure, include a warning sign stating: "DANGER: DOOR UNDER PRESSURE. DO NOT OPEN WITH FAN ON."

b. Lettering Size and Style: At least [**1-inch-**] <**Insert dimension**> high, block style.
c. Material: Lettering engraved in black plastic on a white plastic back. Engraving shall penetrate through black plastic so lettering reads white.
d. Attachment: Attach nameplates to door using high-strength bonding cement and [**stainless steel**]screws.
e. Mounting Location:

1) For access doors without windows, locate top of nameplate [**6 inches**] <**Insert dimension**> from top of door and center in door width.
2) For access doors with windows, locate nameplate directly [**above**] [**or**] [**below**] window frame and center in door width.
3) Align nameplates of all doors for uniform placement.

L. Access Panels:

1. Performance: Leakage as required to satisfy overall unit leakage performance indicated.
2. Fabrication: Formed and reinforced panels of same material and thickness as casing.
3. Fasteners: Adjustable, reusable type for multiple operations without degradation due to reuse.[**Do not use screws capable of stripping.**]
4. Arrangement: Panels removable from exterior side of casing.
5. Gasket: EPDM, neoprene, or santoprene similar to access doors, applied around entire perimeter of panels or frames.
6. Location and Size:

a. Coils[**and Electric Heaters**]: Oversized access panel to allow removal and replacement without impacting adjacent casing.
b. Fans: Oversized access panel to allow removal and replacement of entire fan assembly [**including base**]without impacting adjacent casing.
c. Heat Wheels and Heat Exchangers: Oversized access panel to allow removal and replacement of internal components without impacting adjacent casing.
d. Humidifiers: Oversized access panel to allow removal and replacement without impacting adjacent casing.
e. <**Insert component**>.

7. Nameplates:

a. On each access panel, include a nameplate defining the access to service within. Nameplates shall be included for, but not be limited to, the following:

1) Cooling Coils.
2) Heating Coils.
3) Electric Heaters.
4) Heat Wheels.
5) Fixed Plate Exchangers.
6) Heat Pipe Heat Exchangers.
7) Humidifiers.
8) Supply Fans.
9) Exhaust Fans.
10) Return Fans.
11) <**Insert description**>.

2.8 INTERNAL STRUCTURAL SUPPORTS

A. General:

1. Air-handling unit manufacturer shall design and assemble air-handing unit internal structural supports for attachment and support by air-handling unit structural base.
2. Factory install structural supports for internal support casing if required to comply with casing structural performance.
3. Factory install hoist beams and rails over equipment to comply with performance requirements for service.

B. Structural Member Size and Spacing:

1. Size: Air-handling unit manufacturer shall select size of members and construction to do the following:

a. Withstand the rigors of loading, unloading, shipping, and rigging without damage to air-handling unit components or misalignment of factory-assembled casing and components.
b. Comply with performance requirements indicated.

2. Spacing: Positioned as required to comply with requirements.

C. Materials: [**Structural aluminum, ASTM B209, Alloy 6061 T6**] [**structural carbon steel, ASTM A36/A36M**] [**structural stainless steel, ASTM A276/A276M, Type 304L**] [**or**] [**structural stainless steel, ASTM A276/A276M, Type 316L**] [**as indicated on Drawings**].

1. Structural Supports: [**Angle**] [**channel**] [**I or W beam**] [**or**] [**tube**] shapes selected by air-handling unit manufacturer for application.
2. Hoist Beams for Internal Components (Spanning Full Width of Unit): I or W beam shapes.

D. Carbon-Steel Finish, Mill Galvanized: Mill galvanized carbon steel with weld damaged areas cleaned, prepared and painted with galvanized paint after fabrication.

E. Carbon-Steel Finish: Carbon-steel bases shall be shot-blasted, cleaned, prepared and [**painted**] [**or**] [**hot-dip galvanized**] after fabrication.

2.9 CENTRIFUGAL FAN ARRAYS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Sourcing Option: In lieu of sourcing fan array assemblies from a specialty fan manufacturer, air-handling unit manufacturer has option to furnish in-house fan array assemblies that achieve equal or better performance while complying with other requirements indicated.

C. Operating Performance:

1. Air-handling unit manufacturer shall account for, and include in, submitted fan selections any static pressure drops associated with unit, and system effect due to fan operating in the air-handling unit.

    a. Add additional static pressure to fan scheduled total static pressure.
    b. If fan motor horsepower is increased, notify Architect.

2. Fans shall have sharply rising pressure characteristics at operating point and stable in operation. Fan horsepower characteristics shall be self-limiting and non-loading.
3. Fan speed, brake horsepower, and sound power levels indicated are maximum acceptable.
4. Scheduled motor horsepower, airflow rate, and static pressure are minimum acceptable. Motor horsepower shall be capable of handling maximum horsepower of fan at scheduled speed.
5. As a minimum, fans shall have AMCA class indicated on Drawings.

    a. Fan operating limits shall be in accordance with AMCA 99 for AMCA class indicated.
    b. If AMCA class is not indicated, use AMCA 99 as basis for determining AMCA class.
    c. AMCA class selected shall be capable of accommodating a plus 10 percent increase to fan static pressure indicated on Drawings.

6. Motor starting torque shall exceed fan speed-torque requirements.
7. Airflow Profile:

a. Fan arrangement within fan array shall produce a uniform airflow and velocity profile across air-handling unit air tunnel when measured [**12 inches**] <**Insert dimension**> upstream of fan inlet and [**48 inches**] <**Insert dimension**> downstream of fan inlet.

D. Vibration Balance:

1. Each fan/motor assembly shall be factory balanced to AMCA 204, [**BV-5, Balance Quality Grade G1.0**] [**BV-4, Balance Quality Grade G2.5**] [**BV-3, Balance Quality Grade G6.3**] [**Balance Quality Grade indicated on Drawings**] <**Insert fan vibration balance requirements**> or better through entire operating speed range from minimum speed to maximum speed. If minimum speed is not indicated on Drawings, assume minimum speed to be [**10**] [**20**] <**Insert number**> percent of design speed.
2. Identify and record each speed and speed range within the fan operating range that could cause potential vibration problems.
3. Submit test reports as an informational submittal for Project record.

E. Vibration Isolation: Install vibration isolation on each fan/motor assembly in the fan array, except vibration isolation may be omitted on fans/motor assemblies balanced to AMCA 204, BV-5, with a maximum residual imbalance of 0.22-in./speak, filter in.

F. Operation and Service Requirements:

1. Remaining fans in array shall continue to operate with one or multiple failed fans.
2. Each fan/motor assembly of fan array shall be capable of lock-out/tag-out procedure without interrupting operation of other fans in the array.
3. Each fan/motor assembly shall be controlled through a variable-frequency controller, except for fans with electronically commutated (EC) motors having integral motor controls.

   a. Include a dedicated variable-frequency controller for each fan/motor assembly in the fan array.
   b. If fan array is served from a single variable-frequency controller, include a redundant variable-frequency controller with automatic switchover in event of primary variable-frequency controller failure.

4. A single mechanical, electrical, and control device failure shall not result in a fan array available capacity of less than [**33**] <**Insert number**> percent of air-handling unit total scheduled airflow capacity.
5. Fan wheel/motor assembly shall pass through the air-handling unit access door servicing fans. Entire individual fan assembly shall pass through the door to the room where air-handling unit is located.
6. Design and incorporate features to permit safe, rapid, and economical maintenance.

G. Airflow Measurement, Local Indication, and Remote Monitoring:

1. Each fan within fan array shall include airflow measurement indication in cfm
2. Include airflow totalization of all operating fans in fan array.
3. Airflow measurement instrumentation shall not restrict or deflect air travel through fan and shall not impact fan air and sound performance.

4. Include digital display of individual fan airflow and total fan array airflow on face of fan control panel.
5. Include a 4- to 20-mA output signal for remote monitoring of total fan array airflow.

H. Fan Array Local Control:

1. Include fan control panel with operator interface to control fan array locally through the fan control panel and to switch to control of fan array through a remote-control source.
2. Local control shall include on/off operation [**and speed adjustment**]for entire fan array and each individual fan/motor in fan array.

I. Fan Array Remote Control:

1. Include fan control panel with control interface for remote control.
2. Fan array on/off operation shall be remotely controlled through a single hardwired digital output signal.
3. Fan array speed shall be remotely controlled through a single hardwired analog (4- to 20-mA) output signal.

J. Fan Base, Stackable Fan Units:

1. Mount fan/motor on [**aluminum**] [**galvanized-steel**] [**or**] [**powder-coated steel**] base.
2. Include base and vibration isolators in accordance with requirements indicated.
3. Weld structural members to form a rigid base.
4. Size and design the base construction to withstand the rigors of shipping and rigging.
5. Include the base with lifting lugs or holes.

K. Fan Frame:

1. Construct frame of [**aluminum**] [**galvanized steel**] [**or**] [**powder-coated steel**].
2. Reinforce and brace frame to prevent excessive deflection and pulsation.
3. Include stiffeners to form a rigid frame that is free of structural resonance and vibration.

L. Fan Panel:

1. Construct fan panel of [**continuously welded**] [**aluminum**] [**galvanized steel**] [**or**] [**powder-coated steel**].
2. Reinforce and brace fan panel to prevent excessive deflection and pulsation.
3. Include stiffeners to form a rigid panel that is free of structural resonance and vibration.

M. Fan Inlet Cone:

1. Include a precision-spun or die-formed, matched inlet and wheel cone to ensure streamlined airflow into the wheel and full loading of fan blades.
2. Inlet cone shall be a smooth hyperbolic shape.
3. Inlet cone shall be a single piece, constructed of aluminum or powder-coated steel.
4. Fasten inlet cone to fan panel using bolts, nuts, and washers to provide a positive and secure attachment that can be field removable.

N. Fan Wheel:

1. Fan blades shall be a true hollow airfoil shape, welded to backplate and wheel cone.
2. Construct blades of aluminum, reinforced for AMCA fan class.
3. Design blades to provide smooth airflow over all surfaces of blade.
4. Construct fan hubs of aluminum with integral bracing for extra strength and stiffness.

    a. Castings shall be sound and free of shrink holes, blow holes, cracks, scale, blisters, or other similar injurious defects.
    b. Clean surfaces of castings by blasting, pickling, or any other standard method.
    c. Mold-parting fins and remains of gates and risers shall be chipped, filed, and ground flush.
    d. Design hubs to maintain a high resistance to fatigue and low relative wheel imbalance.

5. Hubs shall be keyed and setscrewed to motor shaft for positive attachment.
6. Construct wheel backplates of aluminum.
7. Select entire rotating assembly so first critical speed is at least [**30**] <**Insert number**> percent greater than fan design speed and at least [**20**] <**Insert number**> percent greater than maximum speed in AMCA fan class.

O. Fan Drive:

1. Direct drive, arrangement 4 in accordance with AMCA 99.
2. Adjust wheel width and diameter to match motor speed while providing performance scheduled.
3. Fasten fan wheel directly to motor shaft using a key in motor shaft and setscrew.
4. Construct motor base and pedestal supports of [**aluminum**] [**galvanized steel**] [**or**] [**powder-coated steel**].
5. Fan Speed Limitation:

    a. Fan speed at design conditions indicated shall not exceed speed on motor nameplate.
    b. Do not select fans to operate at motor speeds greater than motor nameplate.

P. Fan Motors: See "Fan Motors" Article for ac motors.

Q. Fan Motors, Electronically Commutated (EC):

1. Description: EC, variable-speed, dc, programmable brushless motor.
2. Features:

    a. Integral controller/inverter operates wound stator and senses rotor position to electronically commutate the stator.
    b. Controller shall control motor speed either through manual adjustment locally at fan array control panel or through a remote 0- to 10-V-dc control signal.
    c. Motor Mounting: Coordinate with driven equipment; suitable for mounting with motor shaft in either horizontal or vertical position.

3. Performance:

    a. Altitude: Suitable for operation at site altitude.

b. Electrical Characteristics: Suitable for operation with field power source. Coordinate with electrical Installer.
c. Energy Efficiency: Complying with governing energy codes; [**80**] <**Insert number**> percent or higher maintained throughout entire operating range.
d. Power Factor: [**0.9**] <**Insert value**> or higher at full load.
e. Service Factor: 1.0 or higher.
f. Speed Control: Variable, zero to 100 percent.

1) Synchronous speed rotation with no slip losses.
2) Gradual ramp-up to set point upon receiving a start signal.
3) Soft speed change ramps.
4) Able to overcome reverse rotation without impact.
5) Control airflow within 5 percent of set point regardless of static pressure.

g. Temperature: Suitable for operation in ambient temperature range encountered.
h. Thermal Protection:

1) Automatically breaks electrical power to motor when temperature exceeds a safe value.
2) Automatically resets and restores power when temperature returns to normal range.

4. Bearings: Sealed and permanently lubricated ball bearings.
5. Enclosure: ODP or TEFC.
6. Insulation: Class B or Class F.
7. Rotor: Permanent magnet with near zero rotor losses that operates independent of motor current.
8. Materials and Construction:

a. Enclosure and Frame: Aluminum, painted steel, or stainless steel.
b. End Brackets: Cast aluminum.
c. Shaft: Steel or stainless steel.
d. Motor Leads: Pin or screw terminals.
e. Nameplates: Manufacturer's standard.
f. Paint: Manufacturer's standard.

R. Fan Enclosure:

1. Include each fan in fan array with integral single-wall enclosure constructed of solid [**aluminum**] [**galvanized-steel**] [**or**] [**powder-coated steel**] sheet.
2. Enclosure shall not increase fan array length beyond size indicated on Drawings.
3. Enclosure shall not add static pressure loss.
4. Enclosure shall provide a physical separation between operating adjacent fans to prevent negative performance.

S. Fan Sound Silencing Enclosure:

1. Include each fan of fan array with integral sound silencer enclosure to reduce the bare fan discharge sound levels by at least [**8**] [**15**] <**Insert value**> dBs through octave band frequencies from 125 to 8000 Hz.
2. Enclosure shall not increase the fan array length beyond size indicated on Drawings.
3. Silencing enclosure shall not add static pressure loss.

4. Double-wall construction consisting of sound-absorbing insulation sandwiched between a solid metal outer skin and perforated metal inner skin.

    a. Outer Skin Material: [**Aluminum**] [**Galvanized steel**] [**Powder-coated steel**].
    b. Inner Skin: Material [**Aluminum**] [**Galvanized steel**] [**Powder-coated steel**].
    c. Insulation Material: [**Mineral fiber**] [**mineral fiber wrapped in a tight woven fiberglass cloth or polymer sheet**] [**or**] [**fiber free**].

5. Enclosure shall provide a physical separation between operating adjacent fans to prevent a negative performance.

T. Backdraft Damper:

1. Include each fan in the fan array with a backdraft damper at the fan [**inlet**] [**or**] [**outlet**] to prevent air circulation through a fan that is not operating.
2. Open backdraft damper when fan is operating and close when fan is not operating.
3. Design backdraft damper assembly to operate with little to no static pressure loss with fan operating throughout entire operating range from design to minimum airflow.

    a. Add damper pressure loss to fan scheduled total static pressure.
    b. If pressure loss requires a change field electrical power, air-handling unit manufacturer shall be responsible for associated cost of change.

4. Fasten backdraft damper assembly to fan panel or enclosure using hardware designed for easy removal by maintenance personnel.
5. Dampers shall not create measurable additional noise above the sound level of fan.
6. Dampers shall not vibrate or rattle.
7. Construct dampers of extruded aluminum, stainless steel, or powder-coated steel.

U. Blank-off Panels:

1. Include [**one**] [**two**] [**10 percent of**] <**Insert value**> blank-off panel(s) with each air-handling unit fan array for use by operators in the field to prevent air circulation through any of the fans in fan array that are not operating.
2. Design blank-off panels for attachment to fan panels using easily removable and reusable hardware.
3. Construct blank-offs of aluminum, stainless steel, or powder-coated steel sheets, not less than [**0.07 inch**] <**Insert dimension**> thick.
4. Mount fan blank-off panels in the fan inlet access section for convenient operator access and use in the future.

V. Protective Screens:

1. Include easily removable safety screens where fan inlet and outlet are exposed to maintenance personnel, including walk-in air-handling unit plenums.

    a. Safety screens are not required on fan inlets and outlets with backdraft dampers.

2. Expanded-metal or wire screens, fastened to a flat bar perimeter frame.
3. Screens shall comply with OSHA requirements.

4. Screens and frame shall be constructed of aluminum, stainless steel, or powder-coated steel.
5. Fasten screens to fan using removable and reusable hardware designed for easy removal by maintenance personnel.

W. Hardware: Hex-head, high-strength [**carbon steel with corrosion-resistant coating**] [**or**] [**300 series stainless steel**].

X. Nameplates:

1. Construct nameplates and rotation arrows of aluminum or 300 series stainless steel.
2. Securely fasten nameplate and rotation arrow to fan housing using pins or sheet metal screws.
3. Locate nameplates in a highly visible location on motor side of fan.
4. [**Engrave**] [**stamp**] [**or**] [**label**] the following information on nameplate:

    a. Manufacturer, address, phone number, and website address.
    b. Manufacturer model number.
    c. Serial number.
    d. Manufacturing date.
    e. Fan size.
    f. Fan schedule equipment designation (may be listed on a separate nameplate if there is insufficient space).
    g. Design airflow.
    h. Design static pressure.
    i. Design fan speed.
    j. AMCA fan class.
    k. <**Insert requirement**>.

Y. Air-Handling Unit Factory Assembly:

1. Internal Access: Include each fan with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
2. Removal and Replacement: Each fan wheel and motor shall be independently removable and replaceable through a removable access door installed in air-handling unit casing.
3. Stackable Fan Arrays: Construct frame work from aluminum[**, galvanized steel,**] [**, painted steel,**] or stainless steel.
4. Panel-Mounted Fan Array Supports:

    a. Construct a freestanding and self-supporting structural framework to support each fan individually from and independent of adjacent fans.
    b. Construct frame work from aluminum[**, galvanized steel,**] [**, painted steel,**] or stainless steel.

2.10 CENTRIFUGAL PLENUM FANS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain fans from single source from single manufacturer.

C. Operating Performance:

1. Air-handling unit manufacturer shall account for, and include in, submitted fan selections any static pressure drops associated with unit, and system effect due to fan operating in the air-handling unit.

   a. Add additional static pressure to fan scheduled total static pressure.
   b. If fan motor horsepower is increased, notify Architect.

2. Fans shall have sharply rising pressure characteristics at operating point and stable in operation. Fan horsepower characteristics shall be self-limiting and non-loading.
3. Fan speed, brake horsepower, and sound power levels indicated are maximum acceptable.
4. Motor horsepower, airflow rate, and static pressure are minimum acceptable. Motor horsepower shall be capable of handling maximum horsepower of fan at scheduled speed.
5. Fan air performance ratings shall be based on tests in accordance with ASHRAE 51/AMCA 51 and AMCA 210.
6. Base fans sound ratings on AMCA 300 and calculation methods in accordance with AMCA 301.
7. As a minimum, fans shall have AMCA class indicated on Drawings.

   a. Fan operating limits shall be in accordance with AMCA 99 for AMCA class indicated.
   b. If AMCA class is not indicated, use AMCA 99 as basis for determining AMCA class.
   c. AMCA class selected shall be capable of accommodating a plus 10 percent increase to fan static pressure indicated on Drawings.

8. Motor starting torque shall exceed fan speed-torque requirements.

D. Vibration Balance:

1. Each fan/motor assembly shall be factory balanced to AMCA 204, [**BV-5, Balance Quality Grade G1.0**] [**BV-4, Balance Quality Grade G2.5**] [**BV-3, Balance Quality Grade G6.3**] [**Balance Quality Grade indicated on Drawings**] <**Insert fan vibration balance requirements**> or better through entire operating speed range from minimum speed to maximum speed. If minimum speed is not indicated on Drawings, assume minimum speed to be [**10**] [**20**] <**Insert number**> percent of design speed.
2. Identify and record each speed and speed range within the fan operating range that could cause potential vibration problems.
3. Submit test reports as an information submittal for Project record.

E. Operation and Service Requirements:

1. Each fan/motor assembly shall be capable of lock-out/tag-out procedure without interrupting operation of other fans in air-handling unit.
2. Design and incorporate features to permit safe, rapid, and economical maintenance.

F. Fan Base:

1. Mount fan, motor, and drive on a structural-steel or an aluminum base; except, where indicated on Drawings, install fan on a concrete-filled inertia base.

2. Include base and vibration isolators in accordance with requirements indicated.
3. Electrically weld the base.
4. Size and design the base construction to withstand the rigors of shipping and rigging.
5. Include the base with lifting lugs or holes.
6. Construct base with gusseted brackets to accommodate spring isolators indicated.

G. Fan Panel:

1. Construct fan panel of aluminum or powder-coated steel.
2. Support fan wheel and bearings from a structural aluminum or powder-coated steel framework.
3. Reinforce and brace fan panel to prevent vibration and pulsation.
4. Include stiffeners to form a rigid panel that is free of structural resonance and vibration.

H. Fan Inlet and Wheel Cone:

1. Precision-spun or die-formed, matched inlet and wheel cone to ensure streamlined airflow into the wheel and full loading of blades.
2. Inlet and wheel cones shall be hyperbolic.
3. Inlet cone shall be a single piece, constructed of aluminum or powder-coated carbon steel.
4. Fasten inlet cone to fan panel using bolts, nuts, and washers to provide a positive and secure attachment that can be field removable.
5. Inlet cones that are held in place using retaining clips are unacceptable.

I. Fan Wheel:

1. Fan blades shall be a true hollow airfoil shape,[**continuously**] welded to backplate and wheel cone.
2. Construct blades of aluminum, reinforced for AMCA fan class and operating conditions scheduled.
3. Design blades to provide smooth and aerodynamic airflow over all surfaces of blade.
4. Construct fan hubs of cast aluminum or cast iron, ASTM A48/A48M Class 20A and better, with integral bracing for extra strength and stiffness.

    a. Castings shall be sound and free of shrink holes, blow holes, cracks, scale, blisters, or other similar injurious defects.
    b. Clean surfaces of castings by blasting, pickling, or other standard method.
    c. Mold-parting fins and remains of gates and risers shall be chipped, filed, and ground flush.
    d. Design hubs to maintain a high resistance to fatigue and low relative wheel imbalance.

5. Hubs shall be keyed and setscrewed to shaft for positive attachment.
6. Construct the wheel backplates of aluminum.
7. Statically and dynamically balance fan wheel before fan is assembled.
8. Select entire rotating assembly so first critical speed is at least [**30**] <**Insert number**> percent greater than fan design speed and at least [**20**] <**Insert number**> percent greater than maximum AMCA class speed.

J. Fan Drive:

1. Direct drive, arrangement 4 in accordance with AMCA 99 for single-width, single-inlet fans.
2. Adjust wheel width and diameter to match motor speed while providing performance scheduled.
3. Fasten fan wheel directly to motor shaft using a key and setscrew as previously specified.
4. Construct motor base and pedestal of aluminum or powder-coated carbon-steel plate.
5. Fan Speed Limitation: Fan speed at design conditions indicated shall not exceed speed on motor nameplate for direct-drive applications. Do not select fans to operate at motor speeds greater than motor nameplate.

K. Protective Screens: Factory furnish and install protective screens on fan inlet and discharge.

1. [**Expanded metal**] [**or**] [**welded wire**] welded to a [**painted carbon-steel**] [**or**] [**stainless steel**] frame.
2. Screens shall comply with OSHA requirements.
3. Screens shall be constructed of [**painted carbon**] [**or**] [**stainless**] steel.
4. Fasten screens to fan frame for easy removal by maintenance personnel.

L. Welding:

1. Use AWS- or ASME-certified welders to weld materials required by application.
2. [**Where indicated on Drawings,**][**All**]welds shall be continuous full-penetration welds.

M. Hardware: Hex-head, high-strength [**carbon steel**] [**or**] [**300 series stainless steel**].

N. Nameplates:

1. Construct nameplates and rotation arrows of aluminum or 300 series stainless steel.
2. Securely fasten nameplate and rotation arrow to fan housing using pins or sheet metal screws.
3. Locate nameplates in a highly visible location on motor side of fan.
4. [**Engrave**] [**stamp**] [**or**] [**label**] the following information on nameplate:

    a. Manufacturer, address, phone number, and website address.
    b. Manufacturer model number.
    c. Serial number.
    d. Manufacturing date.
    e. Fan size.
    f. Fan schedule equipment designation (may be listed on a separate nameplate if there is insufficient space).
    g. Design airflow.
    h. Design static pressure.
    i. Design fan speed.
    j. AMCA fan class.
    k. <**Insert requirement**>.

O. Air-Handling Unit Factory Assembly:

1. Internal Access: Include each fan with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.

2. Removal and Replacement: Each fan shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
3. Fan Supports:

   a. Construct a freestanding and self-supporting structural framework to support each fan individually from and independent of adjacent fans.
   b. Construct frame work from aluminum[**, galvanized steel,**] [**, painted steel,**] or stainless steel.

2.11 HOUSED CENTRIFUGAL FANS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain fans from single source from single manufacturer.

C. Operating Performance:

1. Air-handling unit manufacturer shall account for, and include in, submitted fan selections any static pressure drops associated with unit, and system effect due to fan operating in the air-handling unit.

   a. Add additional static pressure to fan scheduled total static pressure.
   b. If fan motor horsepower is increased, notify Architect.

2. Fans shall have sharply rising pressure characteristics at operating point and stable in operation. Fan horsepower characteristics shall be self-limiting and non-loading.
3. Fan speed, brake horsepower, and sound power levels indicated are maximum acceptable.
4. Motor horsepower, airflow rate, and static pressure are minimum acceptable. Motor horsepower shall be capable of handling maximum horsepower of fan at scheduled speed.
5. Fan air performance ratings shall be based on tests in accordance with ASHRAE 51/AMCA 51 and AMCA 210.
6. Base fan sound ratings on AMCA 300 and calculation methods in accordance with AMCA 301.
7. As a minimum, fans shall have AMCA class indicated on Drawings.

   a. Fan operating limits shall be in accordance with AMCA 99 for AMCA class indicated.
   b. If AMCA class is not indicated, use AMCA 99 as basis for determining AMCA class.
   c. AMCA class selected shall be capable of accommodating a plus 10 percent increase to fan static pressure indicated on Drawings.

8. Motor starting torque shall exceed fan speed-torque requirements.

D. Vibration Balance:

1. Each fan/motor assembly shall be factory balanced to AMCA 204, [**BV-5, Balance Quality Grade G1.0**] [**BV-4, Balance Quality Grade G2.5**] [**BV-3, Balance Quality Grade G6.3**] [**Balance Quality Grade indicated on Drawings**] <**Insert fan vibration balance requirements**> or better through entire operating speed range from minimum

speed to maximum speed. If minimum speed is not indicated on Drawings, assume minimum speed to be [**10**] [**20**] <**Insert number**> percent of design speed.

2. Identify and record each speed and speed range within the fan operating range that could cause potential vibration problems.
3. Submit test reports as an information submittal for Project record.

E. Operation and Service Requirements:

1. Each fan/motor assembly shall be capable of lock-out/tag-out procedure without interrupting operation of other fans in air-handling unit.
2. Design and incorporate features to permit safe, rapid, and economical maintenance.

F. Fan Base:

1. Mount fan, motor, and drive assembly on an open structural base, except where Drawings indicate an inertia base.
2. Continuously weld base structural members constructed of [**aluminum**] [**carbon steel**] [**or**] [**stainless steel**].
3. [**Air-handling unit**] [**or**] [**fan**] manufacturer to size and design the fan base construction to withstand the rigors of shipping and rigging.
4. Fabricate base with lifting lugs or holes and gusseted brackets to accommodate spring isolators indicated.

G. Fan Housing:

1. Continuously weld housing constructed of [**aluminum**] [**carbon-steel**] [**or**] [**stainless steel**] sheets, plates, and structural shapes.
2. Support fan housing and shaft bearings from a rigid structural framework.
3. Brace fan housing to prevent vibration and pulsation with external stiffeners to form a rigid housing that is free of operating resonance.
4. Extend fan housing side sheets not more than [**1/2 inch**] <**Insert dimension**> past fan scroll.
5. Fan Cut-off: Designed for pressure distribution required by the application.
6. Fan Blast Area: At least [**80**] <**Insert number**> percent of fan outlet area.
7. Wheel Removal: Construct fan housing for fan wheel(s) removal through the inlet opening when the inlet cone is removed.
8. Split Housings: For fans with wheel diameters nominal [**49 inches**] <**Insert dimension**> and larger, include diagonally flanged, gasketed, and bolted split housings.
9. Access Doors: Quick-opening, gasketed, with heavy-duty latches.

    a. Conform to housing contour.
    b. Locate in 5 o'clock or 7 o'clock position about the end of the shaft and position to gain internal access.
    c. Maximize size of square access door up to [**24 inches**] <**Insert dimension**>.

10. Drains: [NPS 1] <**Insert pipe size**> female NPT threaded half coupling welded to lowest point of fan housing. Position the drain connection to accommodate field-installed drain piping. Include each drain coupling with a stainless steel threaded plug.
11. Flanged Discharge Connections: Welded flanged discharge with a matching companion flange having evenly spaced holes for threaded hardware.

12. Flanged Inlet Connections: Welded flanged inlet with a matching companion flange having evenly spaced holes for threaded hardware.

H. Fan Inlet and Wheel Cones:

1. Precision-spun or die-formed, matched inlet and wheel cones with hyperbolic shape to ensure streamlined airflow into the wheel and fully load the blades for efficient aerodynamic performance.
2. Inlet cone shall be a single piece, constructed of [**aluminum**] [**carbon steel**] [**or**] [**stainless steel**].
3. Fasten inlet cone to fan housing using bolts, nuts, and washers to provide a positive and secure attachment that can be removed and replaced in the field.

I. Fan Wheel:

1. Fan blades with true hollow airfoil shape, continuously welded to backplate or centerplate and wheel cone(s).
2. Construct blades of [**aluminum**] [**carbon steel**] [**or**] [**stainless steel**], reinforced for AMCA fan class.
3. Design blades to provide smooth and aerodynamic airflow over all surfaces of blade.
4. Construct fan hubs of [**cast aluminum**] [**cast iron, ASTM A48/A48M Class 20A and better**] [**or**] [**stainless steel**], with integral bracing for extra strength and stiffness.

   a. Castings shall be sound and free of shrink holes, blow holes, cracks, scale, blisters, or other similar injurious defects.
   b. Clean surfaces of castings by blasting, pickling, or other standard method.
   c. Mold-parting fins and remains of gates and risers shall be chipped, filed, and ground flush.
   d. Design hubs to maintain a high resistance to fatigue and low relative wheel imbalance.

5. Key and setscrew hubs to shaft for positive attachment.
6. Construct wheel backplates or centerplates of [**aluminum**] [**carbon steel**] [**or**] [**stainless steel**].
7. Statically and dynamically balance fan wheel before fan is assembled.
8. Select entire rotating assembly so first critical speed is at least [**30**] <**Insert number**> percent greater than fan design speed and at least [**20**] <**Insert number**> percent greater than maximum AMCA class speed.

J. Fan Shafts:

1. Fan shaft shall be one piece, solid [**carbon**] [**or**] [**stainless**] steel, accurately turned, ground, polished, and inspected.
2. Polish shafts at the point of bearing contact to comply with bearing manufacturer's recommended tolerances.
3. Inspect shafts for straightness after the keyways are cut.
4. Coat carbon-steel shafts with a rust-inhibitive coating.

K. Fan Shaft Bearings:

1. Fan bearings shall be foot-mounted type, bolted on a rigid welded steel framework that is integral with, or independent of, the housing.
2. Size bearings for L-10 life of at least [**200,000**] <**Insert value**> hours, a DN factor less than [**200,000**] <**Insert value**> and a load factor less than [**2,700,000**] <**Insert value**> at the maximum fan class load limit horsepower, including belt pull.
3. Select bearings in accordance with [**ABMA 9**] [**and**] [**or**] [**ABMA 11**].
4. Types:

    a. Bearings for Fans with Motor Horsepower up to [10 HP] <**Insert size**>: Single-row ball or spherical bearings, self-aligning, grease lubricated, and housed in a pillow block housing.
    b. Bearings for Larger-Size Fans: Double-row spherical, self-aligning, grease lubricated, and housed in a horizontally split pillow block housing.

5. Grease Fittings:

    a. Extend [**copper**] [**or**] [**plastic**] grease lines to an accessible location within sight of bearing for greasing the bearings without removing guards, inlet screens, linkages, and other appurtenances.
    b. Terminate bearings and extended grease lines with grease gun fittings.

L. Fan Drives: Fan-drive type, belt or direct, as indicated on Drawings.

1. Direct Drives:

    a. Double-Width, Double-Inlet: Arrangement 7 in accordance with AMCA 99.
    b. Single-Width, Single-Inlet: Arrangement [**4**] [**or**] [**5**] in accordance with AMCA 99.
    c. For AMCA arrangements 4 and 5, fasten fan wheel directly to motor shaft using a key and setscrew indicated.
    d. Construct motor base and pedestal for AMCA arrangement 4 and 7 fans of [**aluminum**] [**carbon-steel**] [**stainless steel**] plate.

2. Belt Drives:

    a. Multiple V-Belt Design:

        1) Size two belt drives for at least [**2.0**] <**Insert value**> times the fan motor horsepower.
        2) Size belt drives with more than two belts, for at least [**1.5**] <**Insert value**> times the fan motor horsepower.
        3) Coordinate, with motor manufacturer, the size and location of motor sheave required to satisfy motor L-10 bearing life using motor manufacturer's written instructions.
        4) Sheave and V-belt selections shall be in accordance with manufacturer's published data.

    b. Sheaves:

1) Constant-Speed Applications: Fixed or variable sheaves for applications up to [5 hp] <**Insert size**> and fixed sheaves for applications with larger horsepower.
2) Variable-Speed Applications: Fixed sheaves.
3) Profile machined to Mechanical Power Transmission Association Standards.
4) Construct sheaves of high-strength cast iron having a minimum tensile strength of [**25,000 psi**] <**Insert value**>.
5) Sheave rim speeds shall not exceed [**5000 fpm**] <**Insert value**>.
6) Sheave side wobble and runout, and eccentricity shall be within Mechanical Power Transmission Association and Rubber Manufacturers Association (RMA) tolerances.
7) Balance sheaves to satisfy vibration performance requirements.
8) Mount sheaves on the shaft using a taperlock split and keyed bushing or an integral keyed bushing.

c. V-Belts:

1) V-belts shall be oil resistant, non-static conducting, and high quality in accordance with RMA standards.
2) Classic A, B, C, D, and E, non-cogged, cross sections.
3) Multiple belt drives shall be a matched set with belt tolerances in accordance with RMA standards.
4) Tension belts in accordance with manufacturer's written instructions.

3. Drive Guards: Furnish and factory install fan drive guard(s) for bearing assemblies, rotating shafts, sheaves, belts, couplings, and heat slingers.

a. Arrangement 3 fans do not require guards for bearings on the side opposite the drive.
b. Make provision for motor and fan rpm measurement without removing the guard.
c. Construct the guard of flattened expanded aluminum or steel wrapped around a channel frame, suitably braced to prevent vibration.
d. Paint guards using the same coating as fan, except color shall be safety yellow.
e. Design attachment to fan for easy removal by maintenance personnel using a clamp and latch.

M. Discharge Damper, Counterbalanced Backdraft:

1. Performance:

a. Velocity and Pressure Rating: Suitable for a face velocity of up to [**4000 fpm**] <**Insert value**> and a static pressure differential of [**8.0 inches wg**] <**Insert value**>.
b. Leakage: Not to exceed [**15 cfm/sq. ft.**] <**Insert value**> at a static pressure differential of [**1.0 inch wg**] <**Insert value**>.

2. Construction:

a. Frame: Minimum [**10-gauge-**] <**Insert thickness**> thick, [**galvanized-steel**] [**or**] [**stainless steel**] channel frame. Frame to extend beyond blade in open position.

b. Blades: Double-skin airfoil-type parallel blades, constructed of minimum [**18-gauge-**] <**Insert thickness**> thick, [**galvanized**] [**or**] [**stainless**] steel. Include dividers and bracing to form a rigid framework.
c. Axles: [**Steel**] [**or**] [**stainless steel**]; full length of blade and supported by lubricated ball bearings.

3. Mounting:

a. Mount blade axle linkage [**in**] [**or**] [**out**] of airstream.

4. Seals:

a. Blades: EPDM.
b. Jambs: Stainless steel, compression-type seals.

N. Discharge Damper, Motorized: Where indicated on Drawings, furnish fans with factory-installed automatic dampers assembled complete in all respects to functions intended.

1. Performance:

a. Velocity and Pressure Rating: Suitable for a face velocity of at least [**5000 fpm**] <**Insert value**> and a static pressure differential of [**8.5 inches wg**] <**Insert value**>.
b. Leakage: Not to exceed [**8 cfm/sq. ft. m)**] <**Insert value**> at a static pressure differential of [**4.0 inches wg**] <**Insert value**>.

2. Construction:

a. Frame: Minimum [**10-gauge-**] <**Insert thickness**> thick, [**galvanized-steel**] [**or**] [**stainless steel**] channel frame. Frame to extend beyond blade in open position.
b. Blades: Double-skin airfoil-type parallel blades, constructed of minimum [**14-gauge-**] <**Insert thickness**> thick, [**galvanized**] [**or**] [**stainless**] steel. Include dividers and bracing to form a rigid framework.
c. Axles: Each blade with full length axle supported by lubricated ball bearings. Include thrust bearings for dampers mounted in the vertical orientation.

3. Mounting:

a. Mount blade axle linkage out of airstream.
b. Mount damper to fan discharge so damper blades are perpendicular to fan shaft.
c. Configure linkage assembly to interface with single electric actuator.

4. Seals:

a. Blades: EPDM.
b. Jambs: Stainless steel, compression-type, double seals. Jamb seal shall use an outer standard width seal and a narrow inner seal for maximum compression and minimum leakage when blade is in closed position.

5. Damper Electric Actuator:

a. Furnish and factory install an electric actuator for each automated fan discharge damper.
b. Mount actuator on damper frame.
c. Construct interconnecting linkages, lever, and brackets of [**aluminum**] [**carbon steel**] [**or**] [**stainless steel**]. Paint interconnecting linkages, lever, and brackets to match the fan coating.
d. Action, either modulating or two position, as indicated on Drawings.
e. Fail-safe operation (open, closed, or last position) as indicated on Drawings.
f. Size actuators to do the following:

1) Shut off against fan maximum pressure on fan curve at design speed.
2) Operate the damper with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which damper is subjected.

g. Actuator to include the following:

1) Indicator and graduated scale on each actuator to show open and closed positions at travel limits.
2) Adjustable stops for both maximum and minimum positions.

h. Coordinate control interface requirements with external controls to comply with operation indicated.

O. Shaft Seals:

1. Provide single-width, single-inlet fans with shaft seal(s) where indicated on Drawings.
2. Shaft seal(s) shall minimize fan leakage when operating and not operating.
3. Construct shaft seal of an aluminum or split stainless steel plate with non-asbestos material fitted under the split metal plate and seated around the shaft.
4. Secure split plates to housing using threaded hex-head hardware.
5. Shaft seals shall be replaceable from outside the housing without disturbing the shaft or bearings.
6. Select shaft seal clearances and materials for operating temperature, pressure, and air quality encountered.
7. Shaft seals, including labyrinth, floating bushing, or close clearance annulus, are acceptable alternatives.

P. Protective Screens: Factory furnish and install safety screens on unducted fan inlets and discharge openings.

1. [**Expanded metal**] [**or**] [**welded wire**] welded to a [**painted carbon-steel**] [**or**] [**stainless steel**] frame.
2. Screens shall comply with OSHA requirements.
3. Screens shall be constructed of [**painted carbon steel**] [**or**] [**stainless steel**].
4. Fasten screens to fan for easy removal by maintenance personnel.

Q. Piezometer Ring: Mount at fan inlet cone for airflow measurement.

R. Welding:

1. Use AWS- or ASME-certified welders to weld materials required by application.
2. [**Where indicated on Drawings,**][**All**]welds shall be continuous full-penetration welds.

S. Hardware: Hex-head, high-strength [**carbon steel**] [**or**] [**Type 304 or Type 316 stainless steel**].

T. Nameplates:

1. Construct nameplates and rotation arrows of aluminum or 300 series stainless steel.
2. Securely fasten nameplate and rotation arrow to fan housing using pins or sheet metal screws.
3. Locate nameplates in a highly visible location on motor side of fan.
4. [**Engrave**] [**stamp**] [**or**] [**label**] the following information on nameplate:

    a. Manufacturer, address, phone number, and website address.
    b. Manufacturer model number.
    c. Serial number.
    d. Manufacturing date.
    e. Fan size.
    f. Fan schedule equipment designation (may be listed on a separate nameplate if there is insufficient space).
    g. Design airflow.
    h. Design static pressure.
    i. Design fan speed.
    j. AMCA fan class.
    k. <**Insert requirement**>.

U. Special Fan Construction: Where indicated on Drawings, construct individual fans with the following additional features:

1. Spark-Resistant Construction: Construct fans in accordance with AMCA 99 [**Type A**] [**Type B**] [**Type C**] spark-resistant construction[**where indicated on Drawings**].
2. Heat Slinger: Provide for fans handling air with temperatures exceeding [**150 deg F**] <**Insert temperature**>.

    a. Cast aluminum, split-design, internally-finned rotor to create a strong circulation of air over the shaft and inboard bearing, and reduce heat conduction along the shaft to bearings.
    b. Secure the split halves together using at least two stainless steel bolts and use a setscrew to secure the assembly to fan shaft.

3. Corrosion-Resistant Coating:

    a. Baked phenolic[**, equal to Heresite's "P-4403 Brown Baked Phenolic Coating."**] <**Insert manufacturer's name and product name or designation.**>
    b. Total Dry Film Thickness: [**7**] <**Insert value**> mils.
    c. Application in accordance with manufacturer's written instructions and the following:

        1) Mist bonding pass and allow to flash off for several minutes, but not long enough to allow film to completely dry.
        2) Not less than three crisscross multipasses maintaining a wet-appearing film.

3) Air dry approximately 45 to 60 minutes with ventilation before applying heat.
4) After air dry period has elapsed, raise temperature in recommended increments of 30 minutes until desired temperature is reached.
5) Bake intermediate coats at approximately half the final temperature for 10 to 20 minutes.
6) Final Bake: [400 deg F] <**Insert temperature**> for 1-1/2 hours.

4. <**Insert requirements**>.

V. Air-Handling Unit Factory Assembly:

1. Internal Access: Include each fan with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
2. Removal and Replacement: Each fan shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
3. Fan Supports:

a. Construct a freestanding and self-supporting structural framework to support each fan individually from and independent of adjacent fans.
b. Construct frame work from aluminum[**, galvanized steel,**] [**, painted steel,**] or stainless steel.

2.12 FAN MOTORS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain motors from single source from single manufacturer.

C. Standard: Comply with NEMA MG 1 unless more stringent requirements are indicated.

D. Description: NEMA MG 1, [**Design B**] <**Insert design**>, as required to comply with capacity and torque characteristics; medium-induction motor.

1. Performance:

a. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.
b. Efficiency: NEMA Premium Efficiency rating complying with NEMA MG 1.
c. Motor Horsepower: Minimum size as indicated on Drawings. Motor shall operate fan under all conditions indicated without exceeding motor nameplate and without use of motor service factor.
d. Inverter-Duty Rating: Comply with minimum requirements of Class F or Class H insulation, suitable for "inverter-duty" or "drive-duty" applications in accordance with NEMA MG 1. Motor operation through a variable-frequency controller shall not adversely affect the motor performance, operation, useful life, and warranty.
e. Service Factor: [**1.15**] <**Insert value**>.

f. Temperature Rise: [**Match**] [**One class lower than**] <**Insert requirements**> insulation rating.

E. Enclosure Type: [**See Drawings for motor enclosure type**] [**ODP**] [**or**] **[TEFC**].

F. Shaft Grounding System:

1. Shaft grounding system to protect bearings from induced voltage.
2. Shaft grounding system shall have low drag (less than 0.05 percent of motor horsepower), and shall operate for a minimum of three years without periodic maintenance or adjustments.
3. Mounting: External [**or internal**]to motor enclosure.

G. Frame:

1. Frames with integrally cast feet unless other requirements of driven equipment require a different arrangement.
2. Frame, front and back end brackets, and front and back end bearing intercaps constructed of cast iron, ASTM A48/A48M, Class 25 or better.

H. Rotor:

1. Fabricate rotor frame from die-cast aluminum, copper, or associated alloys.
2. Key rotors to motor shaft.
3. Rotating assembly shall be dynamically balanced to within limits defined in NEMA MG 1.
4. Motors shall have the entire rotating assembly between bearing inner caps coated with a corrosion-resistant coating.

I. Stator:

1. Copper windings shall be spike resistant to withstand 1600 peak V.
2. Entire wound and insulated stator coated with a coating to protect against moisture and corrosion.

J. Shaft:

1. Solid shaft fabricated of [**carbon**] [**Type 304 stainless**] [**Type 316 stainless**] [**Type 416 stainless**] steel, accurately turned, ground and polished, and inspected for accuracy.
2. End of shaft with drilled hole for use in field measurements.

K. Bearings:

1. Grease-lubricated ball or roller bearings.
2. ABMA 11 L-10 motor bearing life of [**100,000**] <**Insert value**> hours.
3. Bearing Lubrication:

a. Factory lubricate motor bearings using a premium moisture-resistant polyurea thickened grease with rust inhibitors suitable for extreme operating temperatures encountered.

b. Coordinate special requirements that may impact lubrication and include appropriate lubrication.

4. Grease Fittings:

a. Equip each bearing housing with an easily accessible grease inlet.
b. Fit grease inlets with a grease fitting and protective fitting cap.
c. Equip inlets with an automatic grease relief fitting to prevent excessive greasing.
d. Equip each bearing housing with grease drain and threaded plug.

L. Conduit Box:

1. Material same as frame.
2. For motor frames 365T and below, furnish conduit boxes sized with internal volumes in accordance with NEMA MG 1.
3. For motor frames larger than 365T, furnish conduit boxes one size larger than NEMA MG 1.
4. Coordinate the location and mounting of conduit box with driven equipment manufacturer.
5. Factory mount conduit box on motor.

M. Grounding: NRTL-listed clamp-type grounding lug mounted in conduit box.

N. Motor Leads:

1. Non-wicking type, Class F temperature rating or better, and permanently numbered over entire length for identification.
2. Lead terminals shall be manufacturer's standard.

O. Condensate Drains:

1. Motor with drain holes at the lowest point for drainage of condensate.
2. Each drain hole with a threaded removable plug.

P. TEFC Motor Fans: Corrosion-resistant construction, non-sparking, metallic or non-metallic, bi-directional, and keyed to shaft.

1. Motor Fan Cover: [**Steel**] [**Same material as frame**].

Q. Hardware: Hex-head, high-strength, zinc-plated carbon steel or stainless steel.

R. Lifting Eyebolts: Eyebolt threaded into frame receptacle and design to prevent moisture and other foreign material from entering motor cavity when eyebolt is removed.

S. Nameplates:

1. Construct nameplates of aluminum or stainless steel and attach to motor frame with aluminum, stainless steel, or brass drive pins.
2. Engrave or stamp data on the nameplate.
3. At a minimum, include nameplate data in accordance with NEMA MG 1.[**Also include ABMA bearing designation for the drive and opposite end bearing.**]

T. Paint: Successfully pass [**500**] [**1000**] [**2000**] <**Insert value**>-hour salt spray test for corrosion in accordance with ASTM B117.

2.13 VIBRATION ISOLATION

A. General:

1. Provide fans inside air-handling units with base and vibration isolation indicated on Drawings.

B. Inertia Bases:

1. Description: Reinforced structural base designed for concrete infill with integral bolting provisions for fan mounting.
2. Design and Performance:

   a. Weight of inertia base including concrete infill a minimum of 1.5 times the operating weight of fan.
   b. Base thickness not less than 1/12 of longest span.
   c. Minimum base thickness is as follows:

      1) Up to15 HP: [**6 inches**] <**Insert thickness**>.
      2) 20 to 50 HP [**8 inches**] <**Insert thickness**>.
      3) 60 to 75 HP [**10 inches**] <**Insert thickness**>.
      4) 100 HP and Larger: [**12 inches**] <**Insert thickness**>.

3. Construction:

   a. Base Materials: [**Structural carbon steel, ASTM A36/A36M**] [**structural stainless steel, ASTM A276/A276M, Type 304L**] [**or**] [**structural stainless steel, ASTM A276/A276M, Type 316L**].

      1) Carbon-Steel Finish, Mill Galvanized: Mill-galvanized carbon-steel bases with weld-damaged areas cleaned, prepared, and painted with galvanized paint after fabrication.
      2) Carbon-Steel Base Finish: Carbon-steel bases cleaned in accordance with SSPC-SP 1, [**SSPC-SP 6/NACE No. 3**] [**SSPC-SP 10/NACE No. 5**] and [**painted**] [**or**] [**hot-dip galvanized**] after fabrication.

   b. Base Structural Members:

      1) Perimeter Members: [**Channel**] [**I or W beam shapes**] [**or**] [**tube**].
      2) Intermediate Members (Spanning Full-Width Base): [**Channel**] [**I or W beam shapes**] [**or**] [**tube**].
      3) Cross Members (Spanning Intermediate Members): [**Angle**] [**channel**] [**or**] [**tube**].

   c. Reinforcing Bars: Carbon steel, ASTM A615/A615M, sized for a maximum stress of 20,000 psi (138 000 kPa) when subjected to both static and dynamic loads, and welded in place.

d. Floor: Design inertia base with solid floor in bottom for concrete placement after base installation. Seal to prevent leakage or seepage.

1) Galvanized-Steel Solid Sheet: ASTM A653/A653M; [**G90**] <**Insert coating**> coating, minimum (nominal) [**18 gauge**] [**16 gauge**] <**Insert value**> thick.
2) Stainless Steel Solid Sheet: ASTM A240/A240M or ASTM A480/A480M; [**Type 304**] [**Type 304L**] [**Type 316**] [**Type 316L**] <**Insert type**>; No. [**2D**] [**4**] <**Insert finish**> finish; minimum (nominal) [**18 gauge**] [**16 gauge**] <**Insert value**> thick.

e. Isolator Brackets: Gusseted, height-saving brackets.
f. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.

4. Air-Handling Unit Factory Assembly: Install fans with inertia bases where indicated on Drawings.

a. Coordinate placement of inertia bases with design of air-handling unit structural base. Make provisions for attachment and support.
b. Coordinate inertia base mounting provisions with spring isolators.

C. Spring Isolators:

1. Performance:

a. Deflection: Minimum deflection indicated on Drawings. Use a greater deflection if required to maintain an isolator efficiency of at least [**98**] <**Insert number**> percent under all operating conditions encountered. Calculate isolator efficiency using actual support conditions considering the rigidity of structure.
b. Laterally stable freestanding open-spring mounting.
c. Spring diameter not less than 0.8 of compressed spring height at rated load and in the installed and operating condition.
d. Reserve travel to solid shall be equal to a minimum of 50 percent of rated deflection and in no case less than 25 percent of rated deflection in an installed and operating condition.
e. Ratio of horizontal stiffness to vertical stiffness equal to approximately one.
f. Design and install so that ends of springs remain parallel.
g. Select springs that are non-resonant with equipment related frequencies and natural frequencies of support structure.
h. Springs shall not take a permanent set when compressed to coil bind.
i. Seismic restraints to limit motion under seismic forces to [**1/4 inch**] <**Insert dimension**>.

2. Construction:

a. Coat springs with PVC or neoprene. Color-code springs to allow positive identification after installation.
b. Construct baseplates, spring retainers, and other components of [**aluminum**] [**galvanized carbon steel**] [**or**] [**stainless steel**]. Etch and paint aluminum components.

c. Use nuts, bolts, and washers and other associated hardware constructed of [**zinc-electroplated carbon steel**] [**or**] [**stainless steel**].
d. Isolators with integral leveling bolts.
e. Baseplates with holes and isolation grommets for bolting.
f. Bond nominal [**1/4-inch-**] <**Insert dimension**> thick, neoprene friction pad to baseplate.

D. Thrust Restraints:

1. In sets of two or more, thrust restraints shall consist of springs in series with neoprene isolators.
2. Coordinate and select deflection of thrust restrains with equipment being restrained.
3. Thrust restraints complete with rods and adjustment nuts, plus angle brackets and backing plates for attachment to substrate and equipment being restrained.

E. Elastomeric Grommets:

1. Elastomeric grommets shall be a combination of neoprene washer and bushing.
2. Elastomer shall be 56-durometer maximum.
3. Grommets formed to prevent bolts from directly contacting the secured item.

F. Flexible Connections:

1. Construct flexible connection [**galvanized-steel**] [**or**] [**stainless steel**] edges firmly attached to waterproof and fire-retardant fabric.
2. Fabric shall be [**6 inches**] <**Insert dimension**> wide or more.
3. Suitable for operation in extreme temperatures encountered.
4. NRTL listed for application and complying with NFPA 90A.

G. Air-Handling Unit Factory Assembly:

1. Use precompression-type height-saving brackets with isolators having [**2-1/2-inch**] <**Insert dimension**> deflection or greater, to limit exposed bolt length.
2. Install spring isolators plumb and adjust isolators that are not plumb under operating conditions to make plumb.
3. Adjust isolators to prevent stress transfer to equipment.
4. Verify that installed isolators and mounting systems permit equipment motion in all directions.
5. Restraint fans with isolated thrust resistors to limit displacement to [**1/4 inch**] <**Insert dimension**>. Design for maximum lateral thrust the fan can develop.
6. Adjust or include additional resilient restraints to flexibly limit fan lateral motion to [**1/4 inch**] <**Insert dimension**> during startup and operation of equipment.
7. Anchor restraints to fixed supports having a stiffness greater than the thrust encountered.
8. Include at least [**2-inch**] <**Insert dimension**> operating clearance between fan bases and walking surface of air-handling unit floor. Before startup, clean out foreign matter between bases and equipment to prevent short circuit.
9. Flexible Connections:

a. Install flexible connections at connections to fans.
b. Install flexible connections in accordance with SMACNA standards and manufacturer's written instructions.

c. Make fabric joints on the flat run, not the corners, with overlap to provide an area sufficient to make a positive seal.
d. Apply adhesive between the fabric layers.
e. Attach connections using screws or bolts.
f. Reinforce fabric if required to keep fabric from collapsing and impacting airflow into fan.

2.14 HYDRONIC COILS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Sourcing Option: In lieu of sourcing hydronic coils from a specialty coil manufacturer, air-handling unit manufacturer has option to furnish in-house hydronic coils that achieve equal or better performance while complying with other requirements indicated.

C. General: Provide air-handling units with hydronic coils where indicated on Drawings.

D. Description: Plate fin coils constructed of staggered tubes mechanically expanded into continuous collars that are die formed into plate fins.

E. Design and Performance:

1. Capacities, face area, and number of rows indicated on Drawings are minimum acceptable.
2. Air pressure drop, water pressure drop, fin spacing, and face velocity indicated on Drawings are the maximum acceptable.
3. Coils shall be counterflow design, air to fluid. Fluid supply shall enter air leaving side of coil and exit air entering side.
4. Design coils to be drainable.

   a. Coils shall have all circuits drainable when coils are installed in horizontal position and level.
   b. Coil supply [**and return**]header shall be furnished with a drain connection at lowest point on header.

5. Design coils to be self-venting.

   a. Supply connection near bottom of supply header.
   b. Return connection near top of return header.
   c. Furnish coil return [**and supply**]header with a vent connection at highest point on header.

6. Coils supply and return piping connections on same end of coil.
7. Coils shall be rated for system operating pressures and temperatures encountered by installation, but not less than [**200 psig**] [**300 psig**] <**Insert pressure**>.
8. Coil selection criteria, unless otherwise indicated on Drawings, are as follows:

   a. Face Velocity: Maximum of [**500 fpm**] <**Insert value**>.
   b. Fluid Tube Velocity (at Design Flow Rate):

1) Maximum: [**6 fps**] <**Insert velocity**>.
2) Minimum: [**3 fps**] <**Insert velocity**>.

c. Fluid Header Velocity: Maximum of [**6 fps**] <**Insert velocity**>.
d. Fin Height: Maximum of [**48 inches**] <**Insert dimension**>.
e. Fin Spacing: Maximum of [**12 fins per inch**] <**Insert spacing**>.

9. Cooling coils shall have no moisture carryover at design conditions. Install moisture eliminators on discharge face of coil if it is necessary to eliminate moisture carryover.

F. Casing and Tube Sheets:

1. Depth: Extend coil casing and tube sheets a minimum of [**1/2 inch**] <**Insert dimension**> beyond face of fins on both entering and leaving sides.
2. Casing and Tube Sheet Materials:

a. Cooling Coils: Stainless steel, ASTM A240/A240M or ASTM A480/A480M, [**Type 304L**] [**or**] [**Type 316L**], No. 2D finish.
b. Heating Coils:

1) Stainless steel, ASTM A240/A240M or ASTM A480/A480M, [**Type 304L**] [**or**] [**Type 316L**], No. 2D finish.
2) Galvanized steel, ASTM A653/A653M, G90 coating.

3. Top and Bottom Casings:

a. Flange face minimum of [**1-1/2 inches**] <**Insert dimension**>; double flange edge for rigidity and ease of removal with secondary flange face minimum of [**1/2 inch**] <**Insert dimension**>.
b. Thickness:

1) Coils with Fin Length of up to [**72 Inches**] <**Insert dimension**>: Minimum of [**16 gauge**] [**14 gauge**] [**12 gauge**] thick.
2) Coils with Fin Length Exceeding [**72 Inches**] <**Insert dimension**>: Minimum of [**16 gauge**] [**14 gauge**] [**12 gauge**] thick.

4. End Tube Sheets:

a. Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
b. Flange face minimum of [**1-1/2 inches**] <**Insert dimension**>.
c. Thickness: Minimum of [**16 gauge**] [**14 gauge**] [**12 gauge**] thick.

5. Intermediate Tube Sheets:

a. Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
b. Space intermediate tube sheets a maximum of [**48 inches**] <**Insert dimension**> o.c. and locate to provide equal spacing between tube sheet across coil tube length.
c. Flange face minimum of [**1/2 inch**] <**Insert dimension**>.
d. Thickness: Minimum of [**16 gauge**] <**Insert thickness**> thick.

6. Holes: Include number, size, and location of holes in casing and end tube sheets required for coil installation.

G. Fins:

1. Materials:

a. Aluminum: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.
b. Copper: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.
c. 90/10 Cupronickel: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.

2. Collars: Full collars for accurate fin spacing and maximum tube contact while leaving no surface of tube exposed.
3. Fin Configuration: [**Flat face fins without ripples**] [**Flat face or enhanced ripple fins as required by performance**].

H. Headers:

1. Construct header of seamless copper, ASTM B75/B75M drawn temper of diameter and wall thickness based on coil size, flow rate, design pressure, design temperature, and circuiting.
2. Tube-to Header Connections: Tube-to-header holes shall intrude inward so landed surface area is three times the core tube thickness, to provide enhanced header to tube joint integrity. Tubes shall evenly extend within the ID of the header no more than 0.12 inch.
3. Header Top and Bottom Caps: End caps shall be die-formed and installed on the ID of header such that the landed surface area is three times the header wall thickness.
4. Drains: Include low point of [**supply**] [**supply and return**] header with a [NPS 1/2] <**Insert pipe size**> drain connection. Extend copper or [**red brass**] [**carbon-steel**] [**stainless steel**] <**Insert material**> pipe through air-handling unit casing and terminate end with male national pipe thread (MNPT). Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
5. Vents: Include high point of [**return**] [**supply and return**] header with a [**NPS 1/2**] <**Insert pipe size**> vent connection. Extend copper or [**red brass**] [**carbon-steel**] [**stainless steel**] <**Insert material**> pipe through air-handling unit casing and terminate end with MNPT. Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
6. Supply and Return Connections:

a. Terminate ends with MNPT.
b. Connections to header shall be either copper tube with brazed ASME B16.18 threaded male adapters or [**red brass**] [**carbon-steel**] [**stainless steel**] <**Insert material**> pipe with machine-threaded MNPT connections. Pipe shall extend through air-handling unit casing and be threaded on both ends to facilitate easy field removal and replacement.
c. Connections [**NPS 2-1/2**] <**Insert pipe size**> and larger shall have a bronze ASME 16.24 threaded flanges attached to threaded connections to provide for a flanged field connection. Select flange class, Class 150 or Class 300, for system pressure and temperature encountered.

7. Protect openings of supply, return, vent, and drain connections with a threaded cap to prevent entry of dirt into the coil.

I. Tubes:

1. Material: Copper, ASTM B75/B75M annealed temper or ASTM B280 drawn temper; [**90/10 cupronickel alloy, ASTM B122/B122M**].
2. Tube Nominal Diameter:1/2 or 5/8 inch selected to provide performance indicated.
3. Tube Nominal Wall Thickness: As required by performance, minimum of [**0.020 inch**] [**0.025 inch**] [**0.035 inch**] <**Insert dimension**> thick.

J. Tube Return Bends: 180-degree bends brazed to tubes; material[**, wall thickness,**] and nominal diameter to match tubes.

1. Tube Return Bend Nominal Wall Thickness: As required by performance, minimum of [**0.020 inch**] [**0.025 inch**] [**0.035 inch**] <**Insert dimension**> thick.

K. Brazing: High-temperature brazing alloy with not less than 5 percent silver when brazing like non-ferrous materials together and more than 30 percent silver when brazing ferrous to non-ferrous materials.

L. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating. See Drawings for coils requiring a corrosion-resistant coating.

M. Coatings: Where indicated on Drawings, coat coils with one of the following coatings for additional corrosion protection:

1. Baked phenolic.
2. Cathodic epoxy.
3. Water-based flexible epoxy polymer.
4. Water-based synthetic flexible polymer.
5. <**Insert coating type**>.

N. Hardware: Use hex-head bolts, nuts, and washers constructed of [**Type 304**] [**or**] [**Type 316**] stainless steel.

O. Nameplate: Aluminum or stainless steel nameplate with brass or stainless steel chain for each coil, with the following data engraved or embossed:

1. Manufacturer name, address, telephone number, and website address.
2. Manufacturer model number.
3. Serial number.
4. Manufacturing date.
5. Coil identification (indicated on Drawings).
6. Coil fin length.
7. Coil fin height.
8. Coil weight with fluid/without fluid.
9. Coil casing material and thickness.
10. Coil fin material and thickness.
11. Coil tube material and thickness.
12. Coil header material and thickness.

13. <**Insert requirements**>.

P. Cleaning: Residual manufacturing oils and solid contaminants shall be removed internally and externally by completely submersing the coil in an environmentally acceptable degreasing solution that is chemically compatible with the coil material.

Q. Air-Handling Unit Factory Assembly:

1. Coil Connections: Extend each coil connection through casing access panel and terminate connections, approximately [**4 inches**] <**Insert distance**> beyond exterior face of access panel, and seal each penetration as indicated. Casing access panels shall be removed and reinstalled with coils installed inside air-handling units.
2. Internal Access: Include each coil with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
3. Removal and Replacement: Each coil shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
4. Supports for Coils:

a. Construct a freestanding and self-supporting structural framework to support each coil individually from and independent of adjacent coils.
b. Construct framework for cooling coils, from aluminum or stainless steel[**structural shapes**].
c. Construct frame work for heating coils from aluminum[**, galvanized steel,**] or stainless steel[**structural shapes**].

2.15 REFRIGERANT COILS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain coils from single source from single manufacturer.

C. General: Provide air-handling units with refrigerant coils where indicated on Drawings.

D. Description: Plate fin coils constructed of staggered tubes mechanically expanded into continuous collars that are die formed into plate fins. Coils shall be counterflow circuited and equipped with pressure-type distributors. Distributor tubes shall be of equal length to ensure equal distribution of refrigerant to each circuit.

E. Circuiting: [**Face**] [**Row**] [**Interlaced**] [**Interlaced and face control**] [**Indicated on Drawings**] <**Insert circuiting type**>.

F. Performance:

1. Capacities, face area, and number of rows indicated on Drawings are minimum acceptable.
2. Air pressure drop, fin spacing, and face velocity indicated on Drawings are the maximum acceptable.
3. Rate coils in accordance with AHRI 410 when tested in accordance with ASHRAE 33.
4. Coil performance variables and selection procedures shall be in accordance with AHRI 410.

5. Coil piping connections on same end of coil.
6. Coils shall be rated for system operating flows, pressures, and temperatures encountered by installation.
7. Coil selection criteria, unless otherwise indicated on Drawings, are as follows:

    a. Face Velocity: Maximum of [**500 fpm**] <**Insert value**>.
    b. Fin Height: Maximum of [**48 inches**] <**Insert dimension**>.
    c. Fin Spacing: Maximum of [**12 fins per inch**] <**Insert spacing**>.

8. Cooling coils shall have no moisture carryover at design conditions. Install moisture eliminators on discharge face of coil if it is necessary to eliminate moisture carryover.

G. Casing and Tube Sheets:

1. Depth: Extend coil casing and tube sheets a minimum of [**1/2 inch**] <**Insert dimension**> beyond face of fins on both entering and leaving side.
2. Casing and Tube Sheet Materials: Stainless steel, ASTM A240/A240M or ASTM A480/A480M, [**Type 304L**] [**or**] [**Type 316L**], No. 2D finish.
3. Top and Bottom Casings:

    a. Flange face minimum of [**1-1/2 inches**] <**Insert dimension**>; double flange edge for rigidity and ease of removal with secondary flange face minimum of [**1/2 inch**] <**Insert dimension**>.
    b. Thickness: Minimum of [**16 gauge**] [**14 gauge**] [**12 gauge**] thick.

4. End Tube Sheets:

    a. Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
    b. Flange face minimum of [**1-1/2 inches**] <**Insert dimension**>.
    c. Thickness: Minimum of [**16 gauge**] [**14 gauge**] [**12 gauge**] thick.

5. Intermediate Tube Sheets:

    a. Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
    b. Space intermediate tube sheets a maximum of [**48 inches**] <**Insert dimension**> o.c. and locate to provide equal spacing between tube sheet across coil tube length.
    c. Flange face minimum of [**1/2 inch**] <**Insert dimension**>.
    d. Thickness: Minimum of [**16 gauge**] <**Insert thickness**> thick.

6. Holes: Include number, size, and location of holes in casing and end tube sheets required for coil installation.

H. Fins:

1. Collars: Full collars for accurate fin spacing and maximum tube contact while leaving no surface of tube exposed.
2. Configuration: [**Flat face fins without ripples**] [**Flat face or enhanced ripple fins as required by performance**].
3. Materials:

a. Aluminum: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.
b. Copper: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.
c. 90/10 Cupronickel: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.

I. Headers:

1. Construct header of seamless copper, ASTM B75/B75M drawn temper of diameter and wall thickness based on coil size, flow rate, design pressure, design temperature, and circuiting.
2. Tube-to Header Connections: Tube-to-header holes shall intrude inward so landed surface area is three times the core tube thickness to provide enhanced header to tube joint integrity. Tubes shall evenly extend within the ID of the header no more than 0.12 inch.
3. Header Top and Bottom Caps: End caps shall be die-formed and installed on the ID of header such that the landed surface area is three times the header wall thickness.
4. Protect openings to prevent entry of dirt into the coil.

J. Tubes:

1. Material: Copper, ASTM B75/B75M annealed temper or ASTM B280 drawn temper.
2. Tube Nominal Diameter: Selected for performance indicated.
3. Tube Nominal Wall Thickness: As required by performance, minimum of [**0.020 inch**] [**0.025 inch**] [**0.035 inch**] <**Insert dimension**> thick.

K. Tube Return Bends: 180-degree bends brazed to tubes; material, wall thickness, and nominal diameter to match tubes.

L. Brazing: High-temperature brazing alloy with not less than 5 percent silver.

M. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating. See Drawings for coils requiring a corrosion-resistant coating.

N. Coatings: Where indicated on Drawings, coat coils with one of the following coatings for additional corrosion protection:

1. Baked phenolic.
2. Cathodic epoxy.
3. Water-based flexible epoxy polymer.
4. Water-based synthetic flexible polymer.
5. <**Insert coating type**>.

O. Hardware: Use hex-head bolts, nuts, and washers constructed of [**Type 304**] [**or**] [**Type 316**] stainless steel.

P. Nameplates: Aluminum or stainless steel nameplate with brass or stainless steel chain for each coil, with the following data engraved or embossed:

1. Manufacturer name, address, telephone number, and website address.
2. Manufacturer model number.
3. Serial number.

4. Manufacturing date.
5. Coil identification (indicated on Drawings).
6. Coil fin length.
7. Coil fin height.
8. Coil weight.
9. Coil casing material and thickness.
10. Coil fin material and thickness.
11. Coil tube material and thickness.
12. Coil header material and thickness.
13. <**Insert requirements**>.

Q. Cleaning: Residual manufacturing oils and solid contaminants shall be removed internally and externally by completely submersing the coil in an environmentally acceptable degreasing solution that is chemically compatible with coil material.

R. Air-Handling Unit Factory Assembly:

1. Coil Connections: Extend each coil connection through casing access panel and terminate connections, approximately [**4 inches**] <**Insert distance**> beyond exterior face of the access panel, and seal each penetration as indicated. Casing access panels shall be removed and reinstalled with coils installed inside air-handling units.
2. Internal Access: Provide each coil with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
3. Removal and Replacement: Each coil shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
4. Supports for Coils:

   a. Construct a freestanding and self-supporting structural framework to support each coil individually from and independent of adjacent coils.
   b. Construct framework for cooling from aluminum or stainless steel[**structural shapes**].

2.16 STEAM COILS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain coils from single source from single manufacturer.

C. General: Provide air-handling units with refrigerant coils where indicated on Drawings.

D. Description: Plate fin coils constructed of tubes mechanically expanded into continuous collars that are die formed into plate fins and specially designed for thermal expansion and contraction of the tubes during coil operation.

1. Distributing-type steam coils of a tube-in-tube design for uniform steam distribution along the entire length of each tube to ensure a consistent temperature rise across the full coil face and accelerate condensate removal.
2. Non-distributing-type steam coils of a single tube design for uniform steam distribution across the entire header and each tube.

E. Design and Performance:

1. Capacities, face area, and number of rows indicated on Drawings are minimum acceptable.
2. Air pressure drop, fin spacing, and face velocity indicated on Drawings are the maximum acceptable.
3. Design coils to be drainable.

   a. Coils shall have all circuits drainable when coils are installed in horizontal position and level.
   b. Coil headers shall be furnished with a drain connection at lowest point on header.

4. Vents: Vent connection at highest point on header.
5. Coil supply and return piping connections on same end of coil.
6. Coils shall be rated for system operating pressures and temperatures encountered by installation, but not less than <**Insert pressure**>.
7. Coil selection criteria, unless otherwise indicated on Drawings, are as follows:

   a. Face Velocity: Maximum of [**500 fpm**] <**Insert value**>.
   b. Fin Height: Maximum of [**48 inches**] <**Insert dimension**>.
   c. Fin Spacing: Maximum of [**12 fins per inch**] <**Insert spacing**>.

F. Casing and Tube Sheets:

1. Depth: Extend coil casing and tube sheets a minimum of [**1/2 inch**] <**Insert dimension**> beyond face of fins on both entering and leaving side.
2. Casing and Tube Sheet Materials:

   a. Stainless steel, ASTM A240/A240M or ASTM A480/A480M, [**Type 304L**] [**or**] [**Type 316L**], No. 2D finish.
   b. Galvanized steel, ASTM A653/A653M, G90 coating.

3. Top and Bottom Casings:

   a. Flange face minimum of [**1-1/2 inches**] <**Insert dimension**>; double flange edge for rigidity and ease of removal with secondary flange face minimum of [**1/2 inch**] <**Insert dimension**>.
   b. Thickness:

      1) Coils with Fin Length of up to [**72 Inches**] <**Insert dimension**>: Minimum of [**16 gauge**] [**14 gauge**] [**12 gauge**] thick.
      2) Coils with Fin Length Exceeding [**72 Inches**] <**Insert dimension**>: Minimum of [**16 gauge**] [**14 gauge**] [**12 gauge**] thick.

4. End Tube Sheets:

   a. Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
   b. Flange face minimum of [**1-1/2 inches**] <**Insert dimension**>.
   c. Thickness: Minimum of [**16 gauge**] [**14 gauge**] [**12 gauge**] thick.

5. Intermediate Tube Sheets:

    a. Tube sheet holes rolled to prevent chaffing of tubes during thermal expansion and contraction.
    b. Space intermediate tube sheets a maximum of [**48 inches**] <**Insert dimension**> o.c. and locate to provide equal spacing between tube sheet across coil tube length.
    c. Flange face minimum of [**1/2 inch**] <**Insert dimension**>.
    d. Thickness: Minimum of [**16 gauge**] <**Insert thickness**> thick.

6. Holes: Include number, size, and location of holes in casing and end tube sheets required for coil installation.

G. Fins:

1. Materials:

    a. Aluminum: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.
    b. Copper: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.
    c. 90/10 Cupronickel: [**0.0060 inch**] [**0.0075 inch**] [**0.0095 inch**] <**Insert dimension**> thick.

2. Collars: Full collars for accurate fin spacing and maximum tube contact while leaving no surface of tube exposed.
3. Fin Configuration: [**Flat face fins without ripples**] [**Flat face or enhanced ripple fins as required by performance**].

H. Headers:

1. Construct header of seamless copper, ASTM B75/B75M drawn temper of diameter and wall thickness based on coil size, flow rate, design pressure, design temperature, and circuiting.
2. Tube-to Header Connections: Tube-to-header holes shall intrude inward so landed surface area is three times the core tube thickness to provide enhanced header to tube joint integrity. Tubes shall evenly extend within the ID of the header no more than 0.12 inch.
3. Header Top and Bottom Caps: End caps shall be die-formed and installed on the ID of header such that the landed surface area is three times the header wall thickness.
4. Drains: Include low point of headers with a [NPS 1/2] <**Insert pipe size**> drain connection. Extend copper or [**red brass**] [**carbon-steel**] [**stainless steel**] <**Insert material**> pipe through air-handling unit casing and terminate end with MNPT. Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
5. Vents: Include high point of headers with a [**NPS 1/2**] <**Insert pipe size**> vent connection. Extend copper or [**red brass**] [**carbon-steel**] [**stainless steel**] <**Insert material**> pipe through air-handling unit casing and terminate end with MNPT. Pipe shall be threaded on both ends to facilitate easy field removal and replacement.
6. Supply and Return Connections:

    a. Terminate ends with MNPT.
    b. Connections to header shall be either copper tube with brazed ASME B16.18 threaded male adapters or [**red brass**] [**carbon-steel**] [**stainless steel**] <**Insert material**> pipe with machine-threaded MNPT connections. Pipe shall extend

through air-handling unit casing and be threaded on both ends to facilitate easy field removal and replacement.

c. Connections [**NPS 2-1/2**] <**Insert pipe size**> and larger shall have a bronze ASME 16.24 threaded flanges attached to threaded connections to provide for a flanged field connection. Select flange class, Class 150 or Class 300, for system pressure and temperature encountered.

7. Protect openings of supply, return, vent, and drain connections with a threaded cap to prevent entry of dirt into the coil.

I. Tubes:

1. Material: Copper, ASTM B75/B75M annealed temper or ASTM B280 drawn temper; [**90/10 cupronickel alloy, ASTM B122/B122M**].
2. Tube Nominal Diameter:5/8 or 1 inch selected to provide performance indicated.
3. Tube Nominal Wall Thickness: As required by performance, minimum of [**0.035 inch**] [**0.049 inch**] <**Insert dimension**> thick.

J. Tube Return Bends: 180-degree bends brazed to tubes; material[**, wall thickness,**] and nominal diameter to match tubes.

1. Tube Return Bend Nominal Wall Thickness: As required by performance, minimum of [**0.020 inch**] [**0.025 inch**] [**0.035 inch**] <**Insert dimension**> thick.

K. Brazing: High-temperature brazing alloy with not less than 5 percent silver when brazing like non-ferrous materials together and more than 30 percent silver when brazing ferrous to non-ferrous materials.

L. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating. See Drawings for coils requiring a corrosion-resistant coating.

M. Coatings: Where indicated on Drawings, coat coils with one of the following coatings for additional corrosion protection:

1. Baked phenolic.
2. Cathodic epoxy.
3. Water-based flexible epoxy polymer.
4. Water-based synthetic flexible polymer.
5. <**Insert coating type**>.

N. Hardware: Use hex-head bolts, nuts, and washers constructed of [**Type 304**] [**or**] [**Type 316**] stainless steel.

O. Nameplate: Aluminum or stainless steel nameplate with brass or stainless steel chain for each coil, with the following data engraved or embossed:

1. Manufacturer name, address, telephone number, and website address.
2. Manufacturer model number.
3. Serial number.
4. Manufacturing date.
5. Coil identification (indicated on Drawings).

6. Coil fin length.
7. Coil fin height.
8. Coil weight with fluid/without fluid.
9. Coil casing material and thickness.
10. Coil fin material and thickness.
11. Coil tube material and thickness.
12. Coil header material and thickness.
13. <**Insert requirements**>.

P. Cleaning: Residual manufacturing oils and solid contaminants shall be removed internally and externally by completely submersing the coil in an environmentally acceptable degreasing solution that is chemically compatible with the coil material.

Q. Air-Handling Unit Factory Assembly:

1. Coil Connections: Extend each coil connection through casing access panel and terminate connections, approximately [**4 inches**] <**Insert distance**> beyond exterior face of the access panel as seal each penetration as indicated. Casing access panels shall be removed and reinstalled with coils installed inside air-handling units.
2. Internal Access: Include each coil with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
3. Removal and Replacement: Each coil shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
4. Supports for Coils:

   a. Construct a freestanding and self-supporting structural framework to support each coil individually from and independent of adjacent coils.
   b. Construct frame work from aluminum[**, galvanized steel,**] or stainless steel[**structural shapes**].

2.17 HEATING COILS WITH INTEGRAL FACE-AND-BYPASS DAMPERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain coils from single source from single manufacturer.

C. General: Provide air-handling units with heating coils with integral face-and-bypass dampers where indicated on Drawings.

D. Description: Horizontal or vertical tube arrangement as indicated on Drawings with integral face-and-bypass dampers and controls installed to control modulating dampers to achieve discharge air temperature set point.

1. Each coil consisting of multiple finned heating elements, each with bypasses and interlocking dampers controlled by electric actuators and a discharge airstream thermostat.

E. Performance:

1. Each coil able to maintain constant discharge air temperature regardless of variations in entering-air temperature with constant [**steam**] [**and**] [**water**] flow through coil.
2. Portioning of air across and around the heating element shall result in a uniform temperature within 5 deg F of average temperature when measured anywhere across a vertical plane located [**24 inches**] [**36 inches**] downstream of leaving face of coil.

F. Casing: [**Galvanized steel**] [**or**] [**Type 304 stainless steel**], minimum of 16 gauge thick. Standard casing shall be extended if required air-handling unit manufacturer to accommodate installation arrangement inside of the air-handling unit.

G. Fins: Rectangular shape, constructed of 0.010-inch-thick aluminum with spacing not closer than 12 fins per inch.

H. Headers: [**Carbon steel**] [**or**] [**copper**], of thickness selected by manufacturer for flow, pressure, and temperature encountered; drain connections at low points, vent connections at high points, and supply and return connections located on discharge face of coil.

1. Insulation: Insulate headers with mineral-fiber insulation covered by a metal jacket.
2. Supply and Return Connections:

    a. Terminate ends with MNPT.
    b. Connections [**NPS 2-1/2**] <**Insert pipe size**> and larger shall have thread-on flanges. Select flange class, Class 150 or Class 300, for system pressure and temperature encountered.

I. Tubes:

1. Materials: [**Copper**] [**90/10 cupronickel**] [**or**] [**carbon steel**].
2. Nominal Diameter: 5/8 inch.
3. Nominal Tube Wall Thickness: As required by performance, minimum of [**0.035 inch**] [**0.049 inch**] thick.

J. Dampers: Clamshell design arranged to modulate airflow across or around individual heating elements. Constructed of [**galvanized steel**] [**or**] [**Type 304 stainless steel**], minimum of 16 gauge thick.

K. Damper Actuators: [**Face**] [**or side**] mounted; electric motor for proportional control, failing in last position.

L. Brazing: High-temperature brazing alloy with not less than 5 percent silver when brazing like non-ferrous materials together and more than 30 percent silver when brazing ferrous to non-ferrous materials.

M. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating. See Drawings for coils requiring a corrosion-resistant coating.

N. Coating: Where indicated on Drawings, coat coil casings and damper assemblies with [**air-dried alkyd enamel**] [**or**] [**baked-epoxy**] corrosion-resistant coating.

O. Hardware: Use hex-head bolts, nuts, and washers constructed of [**zinc-plated carbon steel**] [**or**] [**Type 304 stainless steel**].

P. Nameplate: Aluminum or stainless steel nameplate with brass or stainless steel chain for each coil, with the following data engraved or embossed:

1. Manufacturer name, address, telephone number, and website address.
2. Manufacturer model number.
3. Serial number.
4. Manufacturing date.
5. Coil identification (indicated on Drawings).
6. <**Insert requirements**>.

Q. Air-Handling Unit Factory Assembly:

1. Coil Connections: Extend each coil connection through casing access panel and terminate connections, approximately [**4 inches**] <**Insert distance**> beyond exterior face of the access panel as seal each penetration as indicated. Casing access panels shall be removed and reinstalled with coils installed inside air-handling units.
2. Internal Access: Include each coil with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
3. Removal and Replacement: Each coil shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
4. Supports for Coils:

    a. Construct a freestanding and self-supporting structural framework to support each coil individually from and independent of adjacent coils.
    b. Construct frame work from aluminum[**, galvanized steel,**] or stainless steel[**structural shapes**].

2.18 DRAIN PANS

A. General:

1. Include a drain pan for each cooling[**and heating**] coil and at other locations indicated.
2. Continuously weld drain pan seams, joints, and mitered corners to make the assembled drain pan watertight.
3. Drain pans shall be located under the entire coil and provide full coil coverage including coil return bends and headers.
4. Slope drain pans in multiple directions toward low point drain connection at a uniform slope of at least [**1**] [**2**] percent from high point to low point.
5. Include stainless steel blank-offs to prevent air from bypassing around coil.

B. Intermediate Drain Pans:

1. Where multiple individual horizontally mounted coils are vertically stacked to make a coil bank, install intermediate drain pans under each stacked coil in the coil bank.
2. Material: [**Type 304L**] [**Type 316L**] [**300 series**] stainless steel ASTM A240/A240M or ASTM A480/A480M, a minimum of [**16 gauge**] <**Insert value**> thick.
3. Minimum Depth: [**1.0 inch**] [**1.5 inches**] <**Insert dimension**>.
4. Extend drain pan beyond air entering face of coil casing at least [**3 inches**] <**Insert distance**>.

5. Extend drain pan beyond air leaving face of coil casing at least [**6 inches**] <**Insert distance**>.

    a. Where moisture eliminators are required to prevent moisture carryover, extend drain pan beyond leaving face of moisture eliminator in lieu of leaving face of coil.

6. Drain Pan Connection:

    a. Stainless steel threaded coupling welded to underside of drain pan at lowest point.
    b. Minimum Nominal Connection Size: [**NPS 1**] [**NPS 1.5**] [**NPS 2**] <**Insert pipe size**>.

7. Drain Pipe:

    a. Air-handling unit manufacturer to connect full-size drain pipe to each drain pan connection. Option to use one of following pipe materials:

        1) Copper tube with a bronze threaded male adapter, brazed or solder to end.
        2) Aluminum pipe with threaded MNPT ends.
        3) Stainless steel pipe with threaded MNPT ends.

    b. Extend drain pipe to top of drain pan immediately below.
    c. Include a removable stainless steel support to secure bottom of drain pipe from drain pan below to prevent lateral movement.
    d. In applications where multiple drain pans are stacked, align stacked drains pan connections and pipes for clear vertical flow.

C. Bottom Drain Pans:

1. Mounting Location, Recessed in Floor: Air-handling unit manufacturer has option to recess bottom drain pan into the floor or install drain pan above air-handling unit floor walking surface.
2. Mounting Location, Above Floor: Bottom drain pan shall be installed above air-handling unit floor walking surface. Do not recess drain pan into unit base.
3. Grating: Install removable stainless steel grating on top of drain pan.
4. Double-Wall Construction: Double-wall sheet with space between walls filled with [**1-inch**] <**Insert thickness**> insulation.
5. Material: [**Type 304L**] [**Type 316L**] [**300 series**] stainless steel ASTM A240/A240M or ASTM A480/A480M, a minimum of [**16 gauge**] <**Insert value**> thick.
6. Minimum Depth: [**1.5 inches**] <**Insert depth**>.
7. Extend drain pan beyond air entering face of coil casing at least [**3 inches**] <**Insert distance**>.
8. Extend drain pan beyond air leaving face of coil casing at least [**12 inches**] <**Insert distance**>.

    a. Where moisture eliminators are required to prevent moisture carryover, extend drain pan beyond leaving face of moisture eliminator in lieu of the leaving face of coil.

9. Drain Pan Connection:

a. Stainless steel threaded half-coupling welded to lowest point of drain pan.
b. Location: [**One end**] [**Both ends**] [**See Drawings**] <**Insert requirement**>.
c. Minimum Nominal Connection Size: [**NPS 1**] [**NPS 1.5**] [**NPS 2**] <**Insert pipe size**>.

10. Drain Pipe:

a. Air-handling unit manufacturer to connect full size drain pipe to each drain pan connection. Option to use one of following pipe materials:

1) Copper tube with threaded male adapter, brazed or soldered to ends.
2) Aluminum pipe with threaded MNPT ends
3) Stainless steel pipe with threaded MNPT ends.

b. Extend drain pipe and terminate [**3 inches**] <**Insert distance**> beyond exterior face of casing.

2.19 ELECTRIC HEATERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain heaters from single source from single manufacturer.

C. General:

1. Provide air-handling units with electric heaters where indicated on Drawings.
2. NRTL listed for zero clearance to combustible surface, regardless of heater capacity.

D. Design and Performance:

1. Heaters and installation shall comply with NFPA 70.
2. Scheduled capacity (kW) is minimum acceptable.
3. Air pressure drop and face velocity are maximum acceptable.
4. Rate heaters output capacity at voltage, phase, and hertz indicated on Drawings.
5. Arrange capacity control to minimize stratification.
6. Equally balance heater electrical load for each step across all three phases.
7. Part-Load Operation: Include multiple heaters configured in a [**series**] [**or**] [**parallel**] arrangement with operation staged if required for uninterrupted heater operation over the full range of air-handling unit airflow down to the minimum airflow indicated.

a. Where multiple heaters positioned in a parallel arrangement are required for operation over the full range of air-handling unit airflow, include an automatic isolation damper at the [**inlet**] [**or**] [**discharge**] of inactive heaters to isolate airflow across inactive heaters while other heaters are operating.

E. Heating Elements:

1. Open Elements:

a. Open-coil resistance wire of 80 percent nickel and 20 percent chromium; supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in a frame.
b. Safety Screens: Install safety screens to protect operators from accidentally coming in direct connect with elements.

2. Finned Tubular Elements:

a. Coiled resistance wire of 80 percent nickel and 20 percent chromium; center-mounted and surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
b. Finish finned tubular elements with a baked-on aluminum paint, and mount in a frame.
c. Each element individually removable from terminal box.
d. Use threaded stainless steel element terminals and hardware.

F. Frame: [**Galvanized**] [**or**] [**stainless**] steel; include intermediate element support brackets equally spaced at a maximum of [**36 inches**] <**Insert distance**> o.c. across heater element length.

G. Terminal Box/Control Panel: [**Unit mounted**] [**Remote mounted**] [**Unit or remote mounting arrangement indicated on Drawings**]; with disconnection means and overcurrent protection.

1. Enclosure: NEMA 250, [**Type 1**] [**or**] [**Type 12**] enclosure complying with UL 50.
2. Full face hinged door[**with lock and key latching device(s)**].
3. Factory insulate base of terminal box to prevent condensation from occurring within box.
4. Mount terminal box control panel on exterior surface of air-handling unit casing. Gasket and seal air-handling unit cabinet penetrations.
5. Install a laminated elementary wiring diagram on inside face of heater control panel door or in another protected location than visible be service personnel. Wiring diagram shall match installation.

H. Controls:

1. Safety Controls: Each heater with following factory-mounted safety controls:

a. Disk-type thermal cutout switch with automatic reset.
b. Primary linear thermal limit cutout switch with automatic reset.
c. Secondary linear thermal limit cutout switch with local manual reset.
d. Airflow Proving Switch: Diaphragm-operated pressure differential type; with pressure range selected to ensure reliable operation throughout full range of air-handling unit airflow down to minimum airflow indicated.

2. Staging Control: Magnetic contactors for switching stages of heat except for air-handling units located in occupied spaces, include mercury contactors for switching stages of heat.
3. SCR Control: Silicone-controlled rectifier (SCR) for 100 percent stepless capacity control.
4. Remote Monitoring and Control: Include control devices necessary to interface with remote-control signals including the following:

a. Heater on/off control.

b. Monitoring heater on/off status.
c. High-temperature alarm.
d. Low-airflow alarm.
e. Heater capacity control.
f. <**Insert requirement**>.

I. Electrical:

1. Single-Point Field Power Connection: Install and wire the heater to accommodate a single field electrical connection for electrical power.
2. Disconnecting Means: Provide each heater with a main electrical power, door mounted and interlocking, and disconnecting means to prevent access into panel, unless switched in the off position.

   a. [**Fused disconnect switch**] [**Nonfused disconnect switch**] [**Circuit breaker**] with lockable handle.
   b. Minimum Short-Circuit Current Rating: As required by electrical power distribution system, but not less than [**42,000**] [**65,000**] <**Insert value**> A.

3. Factory install and wire branch circuit fusing, or circuit breakers in accordance with NFPA 70.
4. Pilot Lights: Include labeled pilot lights on face of control panel for the following:

   a. Power on.
   b. Low-airflow alarm.
   c. High-temperature alarm.
   d. One for each stage on.
   e. <**Insert requirement**>.

5. Terminations: Wire terminations and field interface terminations to labeled terminal strips.
6. Control Transformer: Size control circuit transformer for required load, plus 75 VA.
7. Labeling: Label each electrical device with a laminated phenolic tag.
8. Use only NRTL labeled electrical components.

J. Nameplate: Include the following data:

1. Manufacturer name, address, telephone number, and website address.
2. Manufacturer model number.
3. Serial number.
4. Manufacturing date.
5. Coil identification (indicated on Drawings).
6. <**Insert requirements**>.

K. Air-Handling Unit Factory Assembly:

1. Support individual heater assemblies within unit from a structural framework constructed of [**aluminum**] [**galvanized steel**] [**or**] [**stainless steel**].
2. Provide each heater assembly with access from [**downstream**] [**and**] [**or**] [**upstream**] sides.

3. Make provisions in arrangement and installation to mitigate uneven airflow patterns within unit for proper heater operation.

2.20 DIRECT-STEAM-INJECTION PANEL DISTRIBUTION MANIFOLD HUMIDIFIERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain humidifiers from single source from single manufacturer.

C. Description: Prefabricated, direct-steam panel distribution manifold specially designed for steam dispersion in a short distance.

1. [**Horizontal**] [**or**] [**vertical**] header with multiple [**vertical**] [**or**] [**horizontal**], [**nonsteam**] [**steam**]-jacketed tubes.
2. [**Nozzles/metered orifices in conjunction with nonsteam-jacketed manifolds**] [**or**] [**punched orifices/no nozzles in conjunction with steam-jacketed manifolds**] spaced evenly along manifold tubes and providing dry and uniform steam distribution.

D. Design and Performance:

1. Absorption distance within [**12 inches**] [**18 inches**] [**24 inches**] <**Insert dimension**>.
2. Air Pressure Drop: Less than 0.1 inch wg at design velocity.
3. Suitable for pressurized steam applications.

E. Headers and Distribution Tubes:

1. Material: [**Stainless steel**] [**Stainless steel, Type 304**] [**Stainless steel, Type 316**].
2. Insulation: [**Uninsulated**] [**Insulated**] [**Insulated, minimum R-0.5**].

F. Steam Separator: External separator, or separator/baffles integral to header, to provide condensate-free steam to the distribution tubes.

1. Material: [**Stainless steel**] [**Stainless steel, Type 304**] [**Stainless steel, Type 316**].

G. Steam Trap:

1. Material: [**Cast iron**] [**Stainless steel**] [**Stainless steel, Type 304**] [**Stainless steel, Type 316**].
2. Type: [**Inverted bucket**] [**or**] [**float and thermostatic**].
3. Capacity: Sized for a minimum of [**3**] <**Insert number**> times the maximum rated condensate flow of humidifier at [**1/2-psig**] <**Insert value**> differential pressure.

H. Air-Handling Unit Factory Installation:

1. Air-handling unit manufacturer shall furnish and install humidifiers with the size and capacities indicated on Drawings.
2. Extend humidifier piping through the air-handling unit casing and terminate the connections approximately [**4 inches**] <**Insert distance**> beyond the exterior face.
3. Drain Pans: Install condensate drain pans to collect and drain water to exterior of air-handling unit casing.

4. Provide each humidifier with access for inspection, service, and replacement.
5. Each humidifier shall be removable for replacement through a removable access panel in the air-handling unit casing or an access door.
6. Include a freestanding and self-supporting structural [**aluminum or**]stainless steel framework to support each humidifier.

2.21 BAG FILTERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain filters from single source from single manufacturer.

C. Description: Factory-fabricated, dry, extended-surface, unsupported filters with header frames.

D. Performance:

1. Filtration Efficiency, ASHRAE 52.2 MERV Rating: [**11**] [**11A**] [**13**] [**13A**] [**14**] [**14A**] [**15**] [**15A**] [**See Drawings**].
2. Energy Cost Index: Five star rating.
3. Initial Air Pressure Drop: With face velocity of 500 fpm, pressure drop shall not exceed the following:

    a. MERV 11 and MERV 11A:

        1) Depth 12 Inches: 0.28 inch wg.
        2) Depth 15 Inches: 0.26 inch wg.
        3) Depth 22 Inches: 0.24 inch wg.
        4) Depth 30 Inches: 0.23 inch wg.

    b. MERV 13 and MERV 13A:

        1) Depth 12 Inches: 0.52 inch wg.
        2) Depth 15 Inches: 0.48 inch wg.
        3) Depth 22 Inches: 0.38 inch wg.
        4) Depth 30 Inches: 0.34 inch wg.

    c. MERV 14 and MERV 14A:

        1) Depth 12 Inches: 0.67 inch wg.
        2) Depth 15 Inches: 0.55 inch wg.
        3) Depth 22 Inches: 0.45 inch wg.
        4) Depth 30 Inches: 0.41 inch wg.

    d. MERV 15 and MERV 15A:

        1) Depth 15 Inches: 0.81 inch wg.
        2) Depth 22 Inches: 0.62 inch wg.
        3) Depth 30 Inches: 0.53 inch wg.

4. Manufacturer-Recommended Final Air Pressure Drop: [1.0 inch wg].

5. Pressure Differential without Failure: [10 inches wg].
6. Temperature Rating: [158 deg F].

E. Certification:

1. AHRI: Tolerances in accordance with AHRI 850 (I-P) and AHRI 851 (SI).
2. ASHRAE: Tested and rated in accordance with ASHRAE 52.2.
3. UL: UL 900 listed.

F. Size:

1. Nominal size of individual filters indicated on Drawings:
2. Nominal Filter Size:

a. Face: [**24 by 24 inches**] <**Insert dimensions**>.
b. Depth: [**12 inches**] [**15 inches**] [**22 inches**] [**30 inches**] <**Insert dimension**>.

3. Actual Filter Size: Suitable for installation in an industry-standard filter holding frame.

G. Filter Media Surface Area: Each filter shall contain the following minimum media surface area for a filter with a nominal 24-by-24-inch

1. Depth 12 Inches: 39 sq. ft..
2. Depth 15 Inches: 49 sq. ft..
3. Depth 22 Inches: 71 sq. ft..
4. Depth 30 Inches: 97 sq. ft..

H. Construction:

1. Media: Glass-fiber material constructed so individual pockets are maintained in tapered form under rated-airflow conditions by flexible internal supports.[**Coat media with an antimicrobial agent.**]

a. Synthetic mesh backing to provide media protection and support.
b. Multiple stitched pockets sealed to eliminate air bypass through stitch points

2. Header: Filter face with ABS plastic or corrosion-resistant metal header designed for rigidity and to eliminate racking.
3. Adhesive: Fire-retardant bonding adhesive where bonding media to header.

2.22 CARTRIDGE FILTERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain filters from single source from single manufacturer.

C. Description: Factory-fabricated, dry, extended-surface, disposable, air filters with media formed in mini-pleats and arranged in a V-shape pattern.

D. Performance:

1. Filtration Efficiency, ASHRAE 52.2 MERV Rating: [**11**] [**11A**] [**13**] [**13A**] [**14**] [**14A**] [**16**] [**16A**] [**See Drawings**].
2. Energy Cost Index: Five star rating.
3. Initial Air Pressure Drop: With face velocity of 500 fpm, clean filter pressure drop shall not exceed the following:

    a. MERV 11 and MERV 11A: 0.21 inch wg.
    b. MERV 13 and MERV 13A: 0.25 inch wg.
    c. MERV 14 and MERV 15A: 0.27 inch wg.
    d. MERV 16 and MERV 16A: 0.60 inch wg.

4. Manufacturer-Recommended Final Air Pressure Drop: [1.5 inches wg]>.
5. Pressure Differential without Failure: [10 inches wg].
6. Temperature Rating: [175 deg F] <Insert temperature>.

E. Certification:

1. AHRI: Tolerances in accordance with AHRI 850 (I-P) and AHRI 851 (SI).
2. ASHRAE: Tested and rated in accordance with ASHRAE 52.2.
3. UL: UL 900 listed.

F. Size:

1. Nominal size of individual filters indicated on Drawings:
2. Nominal Filter Size:

    a. Face: [**24 by 24 inches**] <**Insert dimensions**>.
    b. Depth: 12 inches.

3. Actual Filter Size: Suitable for installation in an industry-standard filter holding frame.

G. Filter Media Surface Area: Each filter shall contain at least [**200 sq. ft.**] <**Insert area**> for a filter with a nominal 24-by-24-inch face.

H. Construction:

1. Media: Microfine glass media formed into mini-pleats and arranged in V-shape patterns.
2. Media Frame: Plastic or corrosion-resistant metal.
3. Adhesive: Fire-retardant bonding adhesive where bonding media to frame.

2.23 PLEATED PANEL FILTERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain filters from single source from single manufacturer.

C. Description: Factory-fabricated, self-supported, extended-surface, pleated, panel-type, disposable air filters.

D. Performance:

1. Filtration Efficiency, ASHRAE 52.2 MERV Rating: [**8**] [**8A**] [**9**] [**9A**] [**See Drawings**].
2. Energy Cost Index: Five star rating.
3. Initial Air Pressure Drop: With face velocity of 500 fpm, clean filter pressure drop shall not exceed the following:

   a. MERV 8 and MERV 8A:

      1) Depth 1 Inch: 0.23 inch wg..
      2) Depth 2 Inches: 0.31 inch wg.
      3) Depth 4 Inches: 0.27 inch wg..

   b. MERV 9 and MERV 9A:

      1) Depth 2 Inches: 0.30 inch wg.
      2) Depth 4 Inches: 0.27 inch wg.

4. Manufacturer-Recommended Final Air Pressure Drop: [1.0 inch wg].
5. Pressure Differential without Failure: [2 inches wg].
6. Temperature Rating: [200 deg F]

E. Certification:

1. AHRI: Tolerances in accordance with AHRI 850 (I-P) and AHRI 851 (SI).
2. ASHRAE: Tested and rated in accordance with ASHRAE 52.2.
3. UL: UL 900 listed.

F. Size:

1. Nominal size of individual filters indicated on Drawings:
2. Nominal Filter Size:

   a. Face: [**24 by 24 inches**] <**Insert dimensions**>.
   b. Depth: [**1 inch**] [**2 inches**] [**4 inches**].

3. Actual Filter Size: Suitable for installation in an industry-standard filter holding frame.

G. Filter Media Surface Area: Each filter shall contain the following minimum media surface area for a filter with a nominal 24-by-24-inch

1. Depth 1 Inch: 9.8 sq. ft..
2. Depth 2 Inches: 17.3 sq. ft..
3. Depth 4 Inches: 27.7 sq. ft..

H. Construction:

1. Media: [**Glass or**] [**Cotton and**] synthetic blend of fibers arranged in a series of pleats attached to and supported by a corrosion-resistant welded-wire grid.[**Coat media with an antimicrobial agent.**]
2. Filter Media Casing: High wet strength (28-point) beverage board that is bonded around the periphery to eliminate air bypass.

a. Diagonal support members across upstream and downstream filter face constructed of same material as casing shall ensure pleat spacing and stability.

3. Adhesive: Fire-retardant bonding adhesive where bonding media to casing.

2.24 ASHRAE-RATED FILTER HOLDING FRAMES

A. Filter Holding Frames for ASHRAE-Rated Filters:

1. Fabricate filter holding frames with mitered corners and reinforce frame to maintain a durable, rugged, true square shape.
2. Construct frames of [**galvanized**] [**or**] [**stainless**] steel. Use stainless steel frames in applications exposed to corrosive airstreams.
3. For applications with pre-filter and final filters sharing the same filter holding frame, frames shall be suitable for supporting and holding both pre-filter and final filters in frame with both filters serviceable from upstream (entering air) side.
4. Frame Depth: At least [**2.75 inches**] <**Insert dimension**>.
5. Gaskets: Continuous, suitable for same operating temperature as filters.
6. Filter Clips: Each filter holding frame with spring clip fasteners at each corner. Spring clips shall allow filters to be removed and replaced without use of tools.
7. Frames shall be industry-standard size to provide interchangeability of filters from other manufacturers.

B. Air-Handling Unit Factory Installation:

1. Air-handling unit manufacturer shall furnish filters and provide filter holding frames, retaining clips, and filter support structures.
2. Furnish filter quantity, size, type, and performance indicated on Drawings.
3. Install filter frames in a flat vertical position for horizontal airflow.
4. Install holding frames in accordance with manufacturer's written instructions and to prevent passage of unfiltered air. Include additional gaskets as necessary.
5. Secure individual holding frames together to build a multiple filter bank.
6. Construct [**aluminum**] [**galvanized-steel**] [**or**] [**stainless steel**] support structure to hold frames and filters.

a. Design support structure for maximum system operating pressures encountered equal to fan shutoff pressure.
b. Design and fabricate support structure to limit deflection across filter bank to 1/360 of the span when subjected to a [**200-lb**] <**Insert value**> lateral force applied at any point on the filter holding frame assembly.

2.25 ABSOLUTE FILTERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain filters from single source from single manufacturer.

C. Description: Factory-fabricated, disposable, packaged high-efficiency particulate air filters consisting of an anodized aluminum hold frame with media formed into mini-pleats and arranged in a V-shape pattern.

D. Performance:

1. Filtration Efficiency:

a. Rating indicated on Drawings.
b. IEST Rating at 0.3-micron Size: [**95**] [**99.99**] [**99.999**] <**Insert number**> percent.

2. Energy Cost Index: Five star rating.
3. Initial Air Pressure Drop: With face velocity of 500 fpm, clean filter pressure drop shall not exceed the following:

a. Gasket Seal Filters:

1) 95 Percent Efficiency: 0.50 inch wg.
2) 99.99 Percent Efficiency: 1.0 inch wg.
3) 99.999 Percent Efficiency: 1.1 inches wg.

b. Gel Seal Filters:

1) 95 Percent Efficiency: 0.70 inch wg.
2) 99.99 Percent Efficiency: 0.9 inch wg.
3) 99.999 Percent Efficiency: 1.1 inches wg.

4. Manufacturer-Recommended Final Air Pressure Drop: [2.0 inches wg]
5. Pressure Differential without Failure: [10 inches wg]
6. Temperature Rating:

a. Gasket Seal: [175 deg F]Gel Seal: [155 deg F]<**Insert temperature**>.

E. Certification:

1. IEST: Tested and rated in accordance with IEST's "Recommended Practice for Testing HEPA Filters."

a. Comply with IEST-RP-CC001.6.
b. Comply with IEST-RP-CC034.

2. UL: UL 900 listed.

F. Size:

1. Nominal Face Size: [**24 by 24 inches**] [**See Drawings**] <**Insert size**>.
2. Depth: 12 inches.
3. Actual Filter Size: Suitable for installation in an industry-standard filter holding frame.

G. Filter Media Surface Area: Each filter shall contain the following minimum media surface area for a filter with a nominal 24-by-24-inch face:

1. Gasket Seal:

    a. 95 Percent Efficiency390 sq. ft. (36.2 sq. m).
    b. 99.99 Percent Efficiency390 sq. ft. (36.2 sq. m).
    c. 99.999 Percent Efficiency431 sq. ft. (40.0 sq. m).

2. Gel Seal:

    a. 95 Percent Efficiency401 sq. ft. (37.2 sq. m).
    b. 99.99 Percent Efficiency401 sq. ft. (37.2 sq. m).
    c. 99.999 Percent Efficiency401 sq. ft. (37.2 sq. m).

H. Construction for Gasket Seal Filters:

1. Media: Microfine glass media formed into mini-pleats and arranged in a V-shape pattern.

    a. Internal Separators: [**None**] <**Insert type**>.
    b. Media to Filter Frame Seal Material: [**Polyurethane**] <**Insert material**>.
    c. Faceguard Material: [**Aluminum**] [**Stainless steel**] <**Insert material**>.
    d. Faceguard Location: [**None**] [**upstream**] [**and**] [**downstream**].

2. Media-Holding Frame: Anodized aluminum enclosing frame with continuous seamless perimeter [**neoprene**] <**Insert gasket material**> gasket.

    a. Filter Frame to Mounting Frame Seal Location: [**Upstream**] [**Downstream**].

3. Adhesive: Fire-retardant bonding adhesive where bonding media to frame.

I. Construction for Gel Seal Filters:

1. Media: Microfine glass media formed into mini-pleats and arranged in a V-shape pattern.

    a. Internal Separators: [**None**] <**Insert type**>.
    b. Media to Filter Frame Seal Material: [**Polyurethane**] <**Insert material**>.
    c. Faceguard Material: [**Aluminum**] [**Stainless steel**] <**Insert material**>.
    d. Faceguard Location: [**None**] [**upstream**] [**and**] [**downstream**].

2. Media-Holding Frame: Anodized aluminum enclosing frame with gel seal track and elastic [**silicone**] [**urethane**] <**Insert material**> gel sealant.
3. Adhesive: Fire-retardant bonding adhesive where bonding media to frame.

2.26 ABSOLUTE FILTER HOLDING FRAME ASSEMBLY

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain holding frame assembly from absolute filter manufacturer.

C. Description: Holding frame assembly with access for upstream (front) or downstream (back) filter servicing as indicated, specifically designed for absolute filter banks.

1. Gasket Seal: Positive-sealing device to ensure seal between each gasket filter to prevent bypass of unfiltered air. Filter latching mechanism to seat each filter firmly against holding frame surface.
2. Gel Seal: Knife-edge to mate to each filter to prevent bypass of unfiltered air. Positive-locking mechanism for each filter to seat the knife edge into the gel during installation and to remove the filter from the knife edge during filter replacement.

D. Construction:

1. Each filter bank with a factory-assembled filter holding framework consisting of a framework superstructure, a base, bracing, and removable swing bolt assemblies designed to accommodate the scheduled sizes and configuration of absolute filters.
2. Framework:

    a. Nominal 4 inches, minimum 11-gauge-thick-, [**galvanized-steel**] [**or**] [**stainless steel**] channels or tube.
    b. Continuously weld members. After assembly, grind and polish welds to provide a smooth uniform sealing surface.

3. Base:

    a. Continuously weld the framework to a minimum 11-gauge- [**galvanized-steel**] [**or**] [**stainless steel**] base.

4. Filter Attachment:

    a. Equip framework with four swing bolts for each filter.
    b. Include each swing bolt with a bearing clamp and hex nut designed for applying a sufficiently uniform sealing pressure against the periphery of each filter.
    c. Swing bolts shall be constructed of at least 5/16-inch [**zinc electroplated**] [**galvanized**] [**or**] [**stainless**] steel.
    d. Hex nuts shall be capable of being torqued to provide at least 50 percent gasket compression.
    e. Swing bolt assembly shall provide individual sealing of filters.

5. Pre-Filter Frames:

    a. For filter banks with pre-filters attached on the air entering side of absolute filter, include an ASHRAE-rated filter holding frame.
    b. Pre-filter holding frames shall be held in place by swing bolts and allow for installation and removal of pre-filters without disturbing absolute filter seal.

E. Air-Handling Unit Factory Installation:

1. Air-handling unit manufacturer shall furnish filters and provide filter holding frames, retaining clips, and filter support structures.
2. Furnish filter quantity, size, type, and performance indicated on Drawings.
3. Install filter frames in a flat vertical position for horizontal airflow.
4. Install holding frames in accordance with manufacturer's written instructions and to prevent passage of unfiltered air. Include additional gaskets as necessary.

5. Construct aluminum[**, galvanized-steel**] or stainless steel support structure to hold frames and filters.

    a. Design support structure for maximum system operating pressures encountered equal to fan shutoff pressure.
    b. Design and fabricate support structure to limit deflection across filter bank to 1/360 of the span when subjected to a [**400-lb**] <**Insert value**> lateral force applied at any point on the filter holding frame assembly.

2.27 GAS-PHASE FILTERS

A. Gas-Phase Panel-Style Filters:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain filters from single source from single manufacturer.
3. Description: Gas-phase panel filter for installation in a universal ASHRAE-rated filter holding frame.
4. Performance:

    a. Initial Air Pressure Drop: Maximum 0.50 inch wg at a velocity of 500 fpm.
    b. Efficiency: 60 percent ozone-removal efficiency.
    c. Temperature: 155 deg F.

5. Construction:

    a. Filters shall be plastic disposable, loose-fill sorbent[**or refillable**].
    b. Panel shall include perforated face.
    c. Each panel shall contain at least 12 lb of sorbent.

6. Nominal Panel Filter Size:

    a. Face: 24 by 24 inches.
    b. Depth: 2 inches.

7. Media:

    a. Coconut shell activated carbon.
    b. Activated alumina impregnated with potassium permanganate.
    c. Blended activated carbon and alumina impregnated with potassium permanganate.
    d. <**Insert media types for specific applications**>.

8. Pre-Installation Protection: Package each gas-phase filter in a sealed polyethylene bag to prevent unintentional adsorption before installation.
9. Gas-Phase Panel-Style Filter Holding Frames: Use ASHRAE-rated filter holding frames.

B. Gas-Phase Canister-Style Filters:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain filters from single source from single manufacturer.
3. Description: Factory-fabricated, dry, cylindrical canisters containing loose-fill adsorbent media.
4. Performance:
    a. Initial Air Pressure Drop: 0.60 inch wg at a velocity of 500 fpm when 16 cylinders, 24 inches long are installed on frames.
    b. Efficiency: 95 percent removal efficiency at rated airflow.
    c. Temperature:
        1) Plastic Construction: 105 deg F.
        2) Stainless Steel Construction: 140 deg F.
5. Canister Construction:
    a. Material: [**Disposable ABS HDPE plastic**] [**or**] [**factory-refillable stainless steel**].
    b. Perforations around cylinder surface area for air passage through media.
    c. Each canister shall include a mounting assembly with three integral bayonets for mounting to matching cylindrical mounting flange.
    d. Gasket seals.
    e. Each canister with at least 1.5 lb of sorbent per 6 inches of canister length.
    f. Canister to mounting hardware procedure shall form a mechanical connection with a seal limiting air bypass across canister mounting assembly.
6. Filter Size:
    a. Nominal Holding Frame Face: 24 by 24 inches.
    b. Nominal Canister Diameter: 6 inches.
    c. Nominal Canister Length: [**18 inches**] [**24 inches**] [Length indicated on Drawings].
7. Media:
    a. Activated carbon.
    b. Impregnated carbon for corrosive and acid gases.
    c. Activated alumina impregnated with 4 percent potassium permanganate.
    d. Blended activated carbon and activated alumina impregnated with potassium permanganate.
    e. <**Insert media types for specific applications**>.
8. Pre-Installation Protection: Package each gas-phase filter in a sealed polyethylene bag to prevent unintentional adsorption before installation.
9. Canister-Style Gas-Phase Filter Holding Frames:
    a. Holding frames shall be 14-gauge stainless steel with cylindrical sorbent cylinder mounting perforations.
    b. Frame shall be assembled from a single piece of metal and welded at junctures to assure a rigid and durable frame assembly.
    c. Each frame shall hold 16 canisters.

d. Frame with prepunched mounting holes for cylindrical filter fastener attachment and open airflow paths.
e. Frame designed for front or back loading.
f. Frame surface shall have a flat sealing surface to ensure a secure sorbent canister mount when matched with sorbent cylinders and sealing gasket.
g. Cylinder to mounting hardware procedure shall form a mechanical connection forming a tight seal that minimizes air bypass.

C. Air-Handling Unit Factory Installation:

1. Air-handling unit manufacturer shall furnish filters and provide filter holding frames, retaining clips, and filter support structures.
2. Furnish filter quantity, size, type, and performance indicated on Drawings.
3. Install filter frames in a flat vertical position for horizontal airflow.
4. Install holding frames in accordance with manufacturer's written instructions and to prevent passage of unfiltered air. Include additional gaskets as necessary.
5. Construct stainless steel support structure to hold frames and filters.

a. Design support structure for weight of gas-phase filters and maximum system operating pressures encountered equal to fan shutoff pressure.
b. Design and fabricate support structure to limit deflection across filter bank to 1/360 of the span when subjected to a [**800-lb**] <**Insert value**> lateral force applied at any point on the filter holding frame assembly.

2.28 FILTER GAUGES

A. Basis-of-Design Products: Subject to compliance with requirements, provide the following:

1. Gauge: <**Insert manufacturer's name; product name or designation**>.
2. Vent Valves: <**Insert manufacturer's name; product name or designation**>.
3. Static Pressure Sensors: <**Insert manufacturer's name; product name or designation**>.
4. Tubing Compression Fittings: <**Insert manufacturer and product name or designation**>.

B. Provide a gauge to indicate pressure differential between entering and leaving side of each filter bank. Panel filter bank separate from cartridge filter bank.

1. Where multiple filters share a common frame, include a separate gauge for each filter bank.
2. Include a metal spacer constructed of same material as filter frame for one of the filters installed in filter bank to accommodate pressure differential measure across both upstream and downstream filters.

C. Gauge shall have a nominal 4-inch-diameter face.

D. Select range of gauge to be approximately [**twice**] [**three times**] <**Insert range**> the dirty filter pressure drop.

E. Provide each gauge with vent valves to allow for re-zeroing the gauge without removing tubing connections.

F. Include static pressure sensors on entering and leaving side of each filter bank.

G. Air-Handling Unit Factory Assembly:

1. Mount each filter gauge on exterior surface of unit casing near associated filter sections.
2. Mount center of gauges [**60 inches**] <**Insert distance**> above bottom of air-handling unit structural base.
3. Connect static pressure sensors to filter gauges using [**aluminum**] [**copper**] [**or**] [**stainless steel**] tubing and compression type fittings.
4. Support tubing at intervals not greater than [**60 inches**] <**Insert distance**> o.c.

2.29 AUTOMATIC DAMPERS

A. General: Provide air-handling units with automatic dampers where indicated on Drawings.

1. Unless otherwise indicated, use parallel-blade configuration for two-position control, for equipment isolation service, and when mixing two airstreams. For other applications, use opposed-blade configuration.
2. Factory assemble multiple damper sections to provide a single damper assembly of size required by application.
3. Damper actuator shall be factory installed by damper manufacturer as integral part of damper assembly. Coordinate actuator location and mounting requirements with damper manufacturer.

B. Rectangular Dampers with Aluminum Blades:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain dampers from single source from single manufacturer.

3. Performance:

a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
b. Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
c. Velocity: Up to [**4000 fpm**] [**6000 fpm**].
d. Temperature: Minus 40 to plus 185 deg F.
e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
f. Damper shall have AMCA seal for both air leakage and air performance.

4. Construction:

a. Frame:

1) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
2) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
3) Width not less than 5 inches.

b. Blades:

1) Hollow, airfoil, extruded aluminum.
2) Parallel- or opposed-blade configuration as required by application.
3) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
4) Width not to exceed 6 inches.
5) Length as required by close-off pressure, not to exceed 48 inches.

c. Seals:

1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
2) Jambs: Stainless steel, compression type[**; or replaceable, mechanically attached extruded silicone**].

d. Axles: 0.5-inch-diameter, [**plated**] [**or**] [**stainless**] steel, mechanically attached to blades.
e. Bearings:

1) Molded synthetic or stainless steel sleeve mounted in frame.
2) Where blade axles are installed in vertical position, include thrust bearings.

f. Linkage:

1) Concealed in frame.
2) Constructed of aluminum and [**plated**] [**or**] [**stainless**] steel.
3) Hardware: Stainless steel.

g. Additional Corrosion Protection for Corrosive Environments:

1) Include anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch thick.
2) Axles, damper linkage, and hardware shall be constructed of Type 316L grade stainless steel.

5. Airflow Measurement: Where indicated, include damper assembly with integral airflow monitoring.

a. <Double click here to find, evaluate, and insert list of manufacturers and products.>

6. Source Limitations: Obtain damper applications from single source from single manufacturer.

a. Zero- to 10-V dc or 4- to 20-mA scaled output signal for remote monitoring of actual airflow.
b. Accuracy shall be within 5 percent of actual flow rate between the range of minimum and design airflow. For applications with a large variation in range between the minimum and design airflow, configure damper sections and flow measurement assembly as required to comply with stated accuracy over the entire modulating range.
c. Include a straightening device as part of flow measurement assembly to achieve the specified accuracy with configuration indicated.
d. Suitable for operation in untreated and unfiltered air.
e. Include temperature and altitude compensation and correction to maintain accuracy over temperature range encountered at site altitude.
f. Include automatic zeroing feature.

7. Airflow Control: Where indicated, provide damper assembly with integral airflow measurement and control.

a. <Double click here to find, evaluate, and insert list of manufacturers and products.>

8. Source Limitations: Obtain damper assembly from single source from single manufacturer.

a. A factory-furnished and -calibrated controller shall be programmed, in nonvolatile EPROM, with application-specific airflow set point and range.
b. Controller and actuator shall communicate to control the desired airflow.
c. Controller shall receive a zero- to 10-V dc input signal and report a zero- to 20-mA output signal that is proportional to airflow.
d. Airflow measurement and control range shall be suitable for operation between 150 to 2000 fpm.
e. Ambient Operating Temperature Range: Minus 40 to plus 140 deg F.
f. Ambient Operating Humidity Range: 5 to 95 percent relative humidity, noncondensing.
g. Provide unit with control transformer rated for not less than 85 VA. Include transformer with primary and secondary protection and primary disconnecting means. Coordinate requirements with field power connection.
h. Include screw terminals for interface to field wiring.
i. Factory mount electronics within a NEMA 250, Type 1 painted steel enclosure.

C. Rectangular Dampers with Insulated Aluminum Blades:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain dampers from single source from single manufacturer.
3. General: Unless otherwise indicated on Drawings, install insulated aluminum blade dampers in applications where dampers close to outdoors.
4. Performance:

a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure and shall not exceed 4.9 cfm/sq. ft. against 4-inch wg differential static pressure at minus 40 deg F.

b. Pressure Drop: 0.1 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
c. Velocity: Up to 4000 fpm.
d. Temperature: Minus 100 to plus 185 deg F.
e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
f. Damper shall have AMCA seal for both air leakage and air performance.

5. Construction:

a. Frame:

1) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.08 inch thick.
2) C-shaped channel with integral flange(s). Mating face shall be a minimum of 1 inch.
3) Width not less than 4 inches.
4) Entire frame shall be thermally broken by means of polyurethane resin pockets, complete with thermal cuts.
5) Damper frame shall be insulated with polystyrofoam on four sides.

b. Blades:

1) Hollow shaped, extruded aluminum.
2) Blades shall be internally insulated with expanded polyurethane foam and shall be thermally broken. Complete blade shall have an insulating factor of R-2.29 and a temperature index of 55.
3) Parallel- or opposed-blade configuration as required by application.
4) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.08 inch thick.
5) Width not to exceed 6 inches.
6) Length as required by close-off pressure, not to exceed 48 inches.

c. Seals: Blade and frame seals shall be of flexible silicone and secured in an integral slot within the aluminum extrusions.[**Option to use stainless steel compression-type frame seals.**].
d. Axles: 0.44-inch-diameter [**plated**] [**or**] [**stainless**] steel, mechanically attached to blades.
e. Bearings:

1) Bearings shall be composed of a celcon inner bearing fixed to axle, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
2) Where blade axles are installed in vertical position, include thrust bearings.

f. Linkage:

1) Concealed in frame.
2) Constructed of aluminum and [**plated**] [**or**] [**stainless**] steel.
3) Hardware: Stainless steel.

g. Additional Corrosion Protection for Corrosive Environments:

1) Include anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch thick.
2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

D. Industrial-Duty Rectangular Dampers with Steel Airfoil Blades:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain dampers from single source from single manufacturer.

3. Performance:

a. Leakage: Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
b. Pressure Drop: 0.06 inch wg at 2000 fpm across a 48-by-48-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
c. Velocity: Up to 4000 fpm.
d. Temperature: Minus 40 to plus 250 deg F.
e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length, minimum 10 inches wg.

4. Construction:

a. Frame:

1) Material: [**Galvanized steel**] [**Type 304 stainless steel**] [**or**] [**Type 316L stainless steel**], minimum 0.11 inch thick.
2) C-shaped channel with mating face minimum of 1 inch.
3) Width not less than [**3 inches**] [**blade width plus 2 inches**].

b. Blades: Hollow, airfoil shape; constructed of [**galvanized steel**] [**Type 304 stainless steel**] [**Type 316L stainless steel**], minimum 0.06 inch thick.

1) Width not to exceed [**6 inches**] [**8 inches**].
2) Length not to exceed [**36 inches**] [**48 inches**] [**60 inches**].

c. Seals:

1) Blades: Replaceable, mechanically attached EPDM or extruded silicone.
2) Jambs: Stainless steel, double compression type.

d. Axles: 0.5- or 0.75-inch-diameter [**plated**] [**Type 304 stainless**] [**or**] [**Type 316 stainless**] steel, mechanically attached to blades[**and continuous from end to end**].
e. Bearings:

1) Stainless steel sleeve type mounted in frame.
2) Where blade axles are installed in vertical position, provide thrust bearings.

f. Linkage:

1) Face linkage exposed to airstream.
2) Constructed of [**plated steel**] [**Type 304 stainless steel**] [**or**] [**Type 316 stainless steel**].
3) Hardware: [**Type 304**] [**or**] [**Type 316**] stainless steel.

E. Damper Actuators:

1. General:

a. Actuators shall operate related damper(s) with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which damper is subjected.
b. Actuators shall produce sufficient power and torque to close off against the maximum system pressures encountered. Actuators shall be sized to close off against the fan shutoff pressure as a minimum requirement.
c. Total damper area operated by an actuator shall not exceed 80 percent of manufacturer's maximum area rating.
d. Include one actuator for each damper assembly where possible. Multiple actuators required to drive a single damper assembly shall operate in unison.
e. Avoid use of excessively oversized actuators, which could overdrive and cause linkage failure when the damper blade has reached either its full open or closed position.
f. Use jackshafts and shaft couplings in lieu of blade-to-blade linkages when driving axially aligned damper sections.
g. Include mounting hardware and linkages for connecting actuator to damper.
h. Select actuators to fail in desired position in the event of a power failure.
i. Actuator Fail Positions: [**See Drawings.**] [**As indicated below:**]

1) Exhaust Air: [**Close**] [**Last position**] [**Open**].
2) Outdoor Air: [**Close**] [**Last position**] [**Open**].
3) Supply Air: [**Close**] [**Last position**] [**Open**].
4) Return Air: [**Close**] [**Last position**] [**Open**].
5) <**Insert system and fail position**>.

2. Type: Motor operated, with or without gears, electric and electronic.
3. Voltage:

a. [**See Drawings**] [**Voltage selection is delegated to professional designing control system**] [**24 V**] [**120 V**] <**Insert requirement**>.
b. Actuator shall deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
c. Actuator shall function properly within a range of 85 to 120 percent of nameplate voltage.

4. Construction:

a. Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
b. 100 up to 400 W: Gears ground steel, oil immersed, shaft-hardened steel running in bronze, copper alloy, or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel, or cast-aluminum housing.

c. Greater Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.

5. Field Adjustment:

a. Spring return actuators shall be easily switchable from fail open to fail closed in the field without replacement.
b. Provide gear-type actuators with an external manual adjustment mechanism to allow manual positioning of the damper when actuator is not powered.

6. Two-Position Actuators: Single direction, spring return, or reversing type.
7. Modulating Actuators:

a. Capable of stopping at all points across full range, and starting in either direction from any point in range.
b. Control Input Signal:

1) Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for [**zero- to 10-**] [**or**] [**2- to 10-**]V dc [**and**] [**4- to 20-mA**] signals.
2) Pulse-Width Modulation (PWM): Actuator drives to a specified position in accordance with a pulse duration (length) of signal from a dry-contact closure, triac sink, or source controller.
3) Programmable Multifunction:

a) Control input, position feedback, and running time shall be factory or field programmable.
b) Diagnostic feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
c) Service data, including at a minimum, number of hours powered, and number of hours in motion.

8. Position Feedback:

a. [**Equip**] [**Where indicated, equip**] two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of [**open**] [**and**] [**close**] position.
b. [**Equip**] [**Where indicated, equip**] modulating actuators with a position feedback through [**current**] [**or**] [**voltage**] signal for remote monitoring.
c. Include a position indicator and graduated scale on each actuator indicating open and closed travel limits.

9. Fail-Safe:

a. Where indicated, provide actuator to fail to an end position.
b. Internal spring return mechanism to drive-controlled device to an end position (open or close) on loss of power.
c. Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.

10. Integral Overload Protection:

a. Provide against overload throughout the entire operating range in both directions.
b. Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.

11. Damper Attachment:

a. Unless otherwise required for damper interface, provide actuator designed to be directly coupled to damper shaft without need for connecting linkages.
b. Attach actuator to damper drive shaft in a way that ensures maximum transfer of power and torque without slippage.
c. Bolt and set screw method of attachment is acceptable only if included with at least two points of attachment.

12. Temperature and Humidity:

a. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of [**minus 20 to plus 120 deg F**] <**Insert temperature range**>.
b. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from [**5 to 95**] <**Insert numbers**> percent relative humidity, noncondensing.

13. Enclosure:

a. Suitable for ambient conditions encountered by application.
b. Provide actuator enclosure with a heater and controller where required by application.
c. NEMA 250, Type 2 for all applications except <**Insert applications**>.
d. NEMA 250, Type 4 or Type 4X for <**Insert applications**> applications.

14. Stroke Time: Select operating speed to be compatible with equipment and system operation.

a. Operate damper from fully closed to fully open within [**15**] [**60**] [**75**] [**90**] [**150**] <**Insert number**> seconds.
b. Operate damper from fully open to fully closed within [**15**] [**60**] [**75**] [**90**] [**150**] <**Insert number**> seconds.
c. Move damper to failed position within [**5**] [**15**] [**30**] <**Insert number**> seconds.
d. Actuators operating in smoke-control systems shall comply with governing code and NFPA requirements.

15. Sound:

a. Spring Return: 62 dBA.
b. Non-Spring Return: 45 dBA.

2.30 MANUAL BALANCING DAMPERS

A. General: Air-handling unit manufacturer shall furnish and factory install manual balancing dampers inside air-handling units where indicated on Drawings.

B. Rectangular Manual Balancing Dampers with Aluminum Airfoil Blades:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain dampers from single source from single manufacturer.

3. Performance:

a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
b. Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
c. Velocity: Up to 6000 fpm.
d. Temperature: Minus 40 to plus 185 deg F.
e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
f. Damper shall have AMCA seal for both air leakage and air performance.

4. Construction:

a. Frame:

1) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
2) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
3) Width not less than 5 inches.

b. Blades:

1) Hollow, airfoil, extruded aluminum.
2) Parallel- or opposed-blade configuration as required by application.
3) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
4) Width not to exceed 6 inches.
5) Length as required by close-off pressure, not to exceed 48 inches.

c. Seals:

1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
2) Jambs: Stainless steel, compression type.

d. Axles: 0.5-inch-diameter [**plated**] [**or**] [**stainless**] steel, mechanically attached to blades.
e. Bearings:

1) Molded synthetic or stainless steel sleeve mounted in frame.
2) Where blade axles are installed in vertical position, include thrust bearings.

f. Linkage:

1) Concealed in frame.
2) Constructed of aluminum and [**plated**] [**or**] [**stainless**] steel.
3) Hardware: Stainless steel.

g. Locking Regulator:

1) Aluminum or stainless steel standoff with locking regulator mounted to frame in an accessible location for manual adjustment of damper blades.

h. Additional Corrosion Protection for Corrosive Environments:

1) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch thick.
2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

C. Industrial-Duty Manual Balancing Dampers with Airfoil Blades:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain dampers from single source from single manufacturer.

3. Performance:

a. Leakage: Leakage shall not exceed 3 cfm/sq. ft. against 1-inch wg differential static pressure.
b. Pressure Drop: 0.06 inch wg at 2000 fpm across a 48-by-48-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
c. Velocity: Up to 4000 fpm.
d. Temperature: Minus 40 to plus 250 deg F.
e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length, minimum 10 inches wg.

4. Construction:

a. Frame:

1) Material: [**Galvanized steel**] [**Type 304 stainless steel**] [**or**] [**Type 316L stainless steel**], minimum 0.11 inch thick.
2) C-shaped channel with mating face minimum of 1 inch.
3) Width not less than [**3 inches**] [**blade width plus 2 inches**].

b. Blades: Hollow, airfoil shape; constructed of [**galvanized steel**] [**Type 304 stainless steel**] [**Type 316L stainless steel**], minimum 0.06 inch thick.

1) Width not to exceed [**6 inches**] [**8 inches**].
2) Length not to exceed [**36 inches**] [**48 inches**] [**60 inches**].

c. Seals:

1) Blades: Replaceable, mechanically attached EPDM or extruded silicone.

2) Jambs: Stainless steel, double compression type.

d. Axles: 0.5- or 0.75-inch-diameter [**plated**] [**Type 304 stainless**] [**or**] [**Type 316 stainless**] steel, mechanically attached to blades[**and continuous from end to end**].

e. Bearings:

1) Stainless steel sleeve type mounted in frame.
2) Where blade axles are installed in vertical position, provide thrust bearings.

f. Linkage:

1) Face linkage exposed to airstream.
2) Constructed of [**plated steel**] [**Type 304 stainless steel**] [**or**] [**Type 316 stainless steel**].
3) Hardware: [**Type 304**] [**or**] [**Type 316**] stainless steel.

g. Locking Regulator:

1) Stainless steel standoff with locking regulator mounted to frame in an accessible location for manual adjustment of damper blades.

2.31 SMOKE DAMPERS

A. General: Air-handling unit manufacturer shall furnish and factory install smoke dampers inside air-handling units where indicated on Drawings.

B. Rectangular Smoke Dampers with Aluminum Blades:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain dampers from single source from single manufacturer.
3. General: Air-handling unit manufacturer shall furnish and factory install smoke dampers inside air-handling units where indicated on Drawings.
4. Performance:

a. Leakage: In accordance with UL 555S, Class 1.
b. Pressure Drop: 0.05 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
c. Velocity: Up to 4000 fpm.
d. Temperature: 250 deg F.
e. Pressure Rating: 8.0 inches wg.

5. Certification: NRTL listed and labeled in accordance with UL 555S, Class 1.
6. Construction:

a. Frame:

1) Material: ASTM B211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.

2) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
3) Width not less than 5 inches.

b. Blades:

1) Hollow, extruded airfoil shape.
2) Material: ASTM B211, Alloy 6063 T5 aluminum, 0.07 inch thick.
3) Width not to exceed 6 inches.
4) Length as required by close-off pressure, not to exceed 48 inches.

c. Seals:

1) Blades: Replaceable, mechanically attached extruded silicone.
2) Jambs: Stainless steel, compression type.

d. Axles: 0.5-inch-diameter [**plated**] [**or**] [**stainless**] steel, mechanically attached to blades.
e. Bearings:

1) Molded synthetic or stainless steel sleeve mounted in frame.
2) Where blade axles are installed in vertical position, include thrust bearings.

f. Linkage:

1) Concealed in frame.
2) Constructed of aluminum and [**plated**] [**or**] [**stainless**] steel.
3) Hardware: Stainless steel.

C. Rectangular Smoke Dampers with Galvanized-Steel Blades:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain dampers from single source from single manufacturer.
3. General: Air-handling unit manufacturer shall furnish and factory install smoke dampers inside air-handling units where indicated on Drawings.
4. Performance:

a. Leakage: In accordance with UL 555S, Class 1.
b. Pressure Drop: 0.07 inch wg at 1500 fpm across a 24-by-24-inch damper when tested in accordance with AMCA 500-D, figure 5.3.
c. Velocity: Up to 4000 fpm.
d. Temperature: 250 deg F.
e. Pressure Rating: 8.0 inches wg.

5. Certification: NRTL listed and labeled in accordance with UL 555S, Class 1.
6. Construction:

a. Frame:

1) Material: Galvanized steel, minimum 0.06 inch thick.

2) Hat-shaped channel with integral flange(s). Flange mating face shall be a minimum of 1 inch.
3) Width not less than 5 inches.

b. Blades:

1) Hollow, airfoil shape.
2) Material: Galvanized steel, minimum 0.06 inch thick.
3) Width not to exceed 6 inches.
4) Length as required by close-off pressure, not to exceed 48 inches.

c. Seals:

1) Blades: Replaceable, mechanically attached extruded silicone.
2) Jambs: Stainless steel, compression type.

d. Bearings:

1) Stainless steel sleeve type mounted in frame.
2) Where blade axles are installed in vertical position, include thrust bearings.

e. Linkage:

1) Concealed in frame.
2) Constructed of galvanized steel.
3) Hardware: Steel with corrosion-resistant finish.

7. Actuator:

a. Type: Electric, with electrical characteristics compatible with field power supply.
b. Action: [**See Drawings**] [**modulating**] [**or**] [**two position**].
c. Control Signal: Individual damper assemblies with multiple actuators shall be factory wired to operate in unison from a single control signal.
d. Fail Position: Closed or open, as indicated on Drawings.
e. Mounting on Damper: External.
f. Quantity: Provide each damper assembly with least number of actuators possible for application.
g. Speed of Response:

1) Damper blade operation shall have a controlled movement of at least 5 seconds when travelling from open to close to reduce the potential for damage to duct system and connected equipment.
2) Damper closure shall not be instantaneous under any condition.
3) Operating time for completion of 90-degree damper travel, from open to close, or from close to open, shall not exceed the more stringent of the following:

a) NFPA references indicated.
b) Governing codes.
c) [**15 seconds**] <**Insert time**>.

8. Blade Position Switches:

   a. Provide damper assemblies with limit switches to provide remote indication of damper blade positions.
   b. Provide separate limit switches for remote indication of damper blade open position and damper blade closed position.
   c. Actuators equipped with remote position indication as an integral part of actuator is acceptable in lieu of separate limit switches only if actuator with integral remote position indication is NRTL listed in accordance with UL 555S.

2.32 DUCT SILENCERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

1. Duct Silencer Sourcing Option: In lieu of sourcing duct silencers from a specialty duct silencer manufacturer, air-handling unit manufacturer has option to furnish in-house silencers that achieve equal or better performance while complying with other requirements indicated.

   a. Full-height duct silencers baffles shall span from floor to roof of air-handling unit air tunnel and consist of multiple baffles aligned to fill the entire cross-sectional area of air-handling unit air tunnel. In this alternative, the air-handling unit casing shall serve as the duct silencer casing.

B. General: Air-handling unit manufacturer shall furnish and install duct silencers and associated support structures inside air-handling units where indicated on Drawings.

1. Unless otherwise indicated on Drawings, select face area of silencers to fill the entire cross-sectional area of air-handling unit air tunnel.
2. Silencer Type: [**Dissipative**] [**Reactive (packless)**] [**Type, either dissipative or reactive (packless), indicated on Drawings**].
3. Factory fabricated.
4. Fire-Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials with flame-spread index not exceeding 25 and smoke-developed index not exceeding 50; ASTM E84.
5. Airstream Surfaces: Surfaces in contact with airstream shall comply with requirements in ASHRAE 62.1.

C. Ratings and Performance:

1. Duct silencer manufacturer shall publish performance for dynamic insertion loss (DIL), self-noise power levels, and airflow static pressure loss based on results of performance testing indicated.
2. Duct silencer manufacturer shall test duct silencers in accordance with ASTM E477 in a qualified nationally recognized independent testing laboratory or manufacturer's National Voluntary Lab Accreditation Program-accredited laboratory.

   a. Conduct tests with air flowing through duct silencers at not less than three different flow rates and with no airflow.
   b. Test methods shall eliminate effects due to end reflection, vibration, flanking transmission, and standing waves in the test chamber.

3. DIL is not less than values indicated on Drawings.
4. Silencer self-generated noise shall not increase system sound level.
5. Static pressure loss not to exceed values indicated on Drawings.
6. Structural Performance:

   a. Design casing for differential air pressure of 8 inches wg (2000 Pa) between.
   b. Reinforce duct silencer casing to limit deflection to 1/200 of span.

D. Construction: Fabricate rectangular silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations. Do not use mechanical fasteners for individual unit assemblies.

1. Casing:

   a. Unless otherwise indicated, construct outer casing in accordance with ASHRAE and SMACNA standards for construction of high-pressure rectangular ductwork.
   b. Casing seams and joints shall be lock formed and mastic filled, or continuously welded.
   c. Materials and Thickness:

      1) Aluminum, ASTM B 209 Alloy 3003-1114, Smooth Finish:

         a) Outer Casing: Solid, minimum [**0.040 inch**] [**0.063 inch**] <**Insert dimension**> thick.
         b) Baffles: Perforated, minimum [**0.032 inch**] [**0.040 inch**] <**Insert dimension**> thick for sizes through [**24 inches**] <**Insert dimension**> tall and [**0.040 inch**] [**0.063 inch**] <**Insert dimension**> thick for larger sizes.

      2) Galvanized Steel, ASTM A653/A653M, [**G60**] [**or**] [**G90**] Finish:

         a) Outer Casing: Solid, minimum [**20 gauge**] [**22 gauge**] <**Insert thickness**> thick.
         b) Baffles: Perforated, minimum [**24 gauge**] [**26 gauge**] <**Insert thickness**>for sizes through [**24 inches**] <**Insert dimension**> tall and [**20 gauge**] [**22 gauge**] <**Insert thickness**> for larger sizes.

      3) Stainless Steel, ASTM A240/A240M or ASTM A480/A480M:

         a) Outer Casing: Solid, minimum [**20 gauge**] [**22 gauge**] <**Insert thickness**> thick.
         b) Baffles: Perforated, minimum [**24 gauge**] [**26 gauge**] <**Insert thickness**> for sizes through [**24 inches**] <**Insert dimension**> tall and [**20 gauge**] [**22 gauge**] <**Insert thickness**> for larger sizes.

   d. Duct Silencer Material Applications:

      1) Exhaust Air, General: [**Aluminum**] [**galvanized steel**] [**Type 304L stainless steel**] [**or**] [**Type 316L stainless steel**].
      2) Exhaust Air, Hazardous: [**Aluminum**] [**galvanized steel**] [**Type 304L stainless steel**] [**or**] [**Type 316L stainless steel**].

3) Mixed Air: [**Aluminum**] [**galvanized steel**] [**Type 304L stainless steel**] [**or**] [**Type 316L stainless steel**].
4) Outdoor Air: [**Aluminum**] [**galvanized steel**] [**Type 304L stainless steel**] [**or**] [**Type 304 stainless steel**].
5) Return Air: [**Aluminum**] [**galvanized steel**] [**Type 304L stainless steel**] [**or**] [**Type 316L stainless steel**].
6) Supply Air: [**Aluminum**] [**galvanized steel**] [**Type 304L stainless steel**] [**or**] [**Type 316L stainless steel**].
7) <**Insert material application**>.

2. Dissipative-Type Duct Silencer Fill Materials:

a. Inert, vermin-proof, and moistureproof inorganic mineral or glass fiber of a density sufficient to obtain the acoustic performance indicated. Fiber-free fill materials are an acceptable alternative to fiber fill materials if complying with other requirements.
b. Pack fill under not less than [**5**] <**Insert number**> percent compression.
c. Fill material and coverings shall not exceed the following values when tested in accordance with ASTM E84, NFPA 255, and UL 723:

1) Flame-Spread Index: 25.
2) Smoke-Developed Index: 50.
3) Fuel Contribution: 20.

d. Protective Coverings for Fiber Fill Materials:

1) Except for silencers used in exhaust applications, completely cover silencer fiber fill materials with a protective covering, such as a tightly woven fiberglass fabric, to prevent particle contamination of airstream without degrading silencer acoustical performance.
2) For silencers located in airstreams filtered by absolute filters and where located in potentially hazardous exhaust airstreams, enclose the fiber fill material in a polymer sheeting to prevent contaminating airstream without impacting air cleanliness and hygiene. Offset polymer sheeting with honeycomb standoff to prevent polymer sheeting from coming in direct contact with perforated baffles.

3. Reactive-Type (Packless) Duct Silencer Baffles: Controlled impedance membranes and broadly tuned resonators without absorptive fill material.
4. Removable Baffles: Design and construct baffles to be easily removable for purposes of cleaning and replacement.

E. Factory Assembly:

1. Install duct silencers in correct direction with respect to airflow.
2. Manufacturer's written installation instructions shall not be compromised.
3. Seal penetrations through duct silencer baffles using a sealant.
4. Install duct silencers with baffles oriented in the vertical position.
5. Duct silencer banks consisting of multiple individual duct silencers shall be as follows:

a. Structurally reinforced to support loading and limit deflection to 1/200 of span.

b. Provided with a continuous nosing to cover all joints of adjoining duct silencers. Nosing shall be constructed of same material as duct silencers and attached by friction fit, crimping, or button punch.
c. Fastened together using [**zinc-plated**] [**or**] [**stainless**] steel sheet metal screws that are spaced at not more than [**6 inches**] <**Insert dimension**> apart, starting at corners.

F. Cleaning:

1. After assembly, clean duct silencers with HEPA-filtered vacuum machines and then wipe all surfaces with a cleaning agent, using clean rags.

2.33 ANTIMICROBIAL ULTRAVIOLET (UV) LAMP SYSTEMS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain lamp systems from single source from single manufacturer.

C. Description: UV-C lamp system consisting of power supply, wiring, lamp(s), plug(s), and holder(s) used for ultraviolet germicidal irradiation (UVGI) of cooling coil and condensate drain pan.

1. Factory assembled and engineered by a qualified design professional.

D. Certification: NRTL listed and labeled in accordance with UL 153, UL 1598, and UL 1995; UL Category Code ABQK; HVAC accessories; air-duct mounted.

E. Performance:

1. Operating Conditions: Suitable for operation in extreme conditions of the airstream encountered.

a. Relative humidity range not less than 5 to 100 percent.
b. Temperature range not less than [**34 to 158 deg F**] <**Insert temperature range**>.
c. Velocity range not less than [**0 to 600 fpm**] <**Insert velocity range**>.

2. Irradiation Intensity: Install sufficient quantity of UV-C lamps to provide an average irradiation intensity of [**500**] [**1000**] [**2000**] <**Insert value**> microwatts/sq. cm over coil face and exposed surfaces of drain pan.
3. Irradiation Intensity: Install sufficient quantity of UVGI fixtures to provide an average irradiation intensity indicated on Drawings.

a. Submit calculations indicating high, low, and average irradiation intensity level across coil face area and drain pan.
b. Take irradiation intensity measurements of factory assembly before air-handling unit shipment to determine results and confirm compliance with requirements. Document and submit measurement results confirming compliance.
c. Intensity calculations shall be based on average output over a lamp life of [**9000**] <**Insert number**> hours and account for light output degradation over the lamp life.

4. Lamp Life: Minimum of [**9000**] <**Insert number**> hours.
5. Light Output Degradation: Reduction in light output shall not exceed [**15**] [**20**] <**Insert number**> percent of initial lamp output over the rated lamp life.

F. Construction:

1. Lamps:

   a. Type: High output, hot cathode; non-ozone producing.
   b. Output: UV-C energy, primarily at the 254-nm wavelength with a 360-degree energy distribution.
   c. Protective Sleeve: Hermetically sealed to provide protection against lamp breakage and to ensure that lamp contents from a broken lamp are contained.
   d. Labeling: Lamp wattage and model number visibly printed on all lamps.
   e. Mercury Content: Less than 8 Mg of mercury in each lamp.
   f. Lamp Sourcing: Commercially sourced from more than one manufacturer for future replacement. Proprietary lamps available from only one manufacturer are unacceptable.

2. Lamp Holders:

   a. UV- and moisture-resistant materials designed to connect the lamp to the plug and ensure a watertight connection.
   b. Adjustable positioning.

3. Wiring Loom: UV-C-resistant jacket materials with internal aluminum/Mylar shield.

   a. Conduit: Loom covered with NRTL-listed flexible metal conduit, aluminum, or stainless steel.

4. Power Supply: NRTL listed, single phase, 120 or 277 V ac as indicated, with a programmed rapid start.

   a. Power Factor: High power factor, Class P, Sound Rated A, Type 1 Outdoor, and with inherent thermal protection and without polychlorinated biphenyl.
   b. Wiring Harness: Plug and play.
   c. Electrical Connection: Single electrical connection[**with service disconnect**].

5. Enclosures: NEMA 250, [**Type 1**] [**Type 4**] constructed of [**painted carbon steel**] [**stainless steel**] <**Insert material**>.

G. Air-Handling Unit Factory Assembly:

1. Install UV-C lamp systems in accordance with manufacturer's written instructions.
2. Location: Install UV-C lamp system array [**immediately downstream of cooling coil bottom drain pan**] [**at locations indicated on Drawings**] <**Insert location within air-handling unit**>.
3. UV-C Lamp System Support Assembly: [**Aluminum**] [**or**] [**300 series grade stainless steel**] framework rigidly attached to air-handling unit casing and adequately braced to provide ridge support of UV-C lamp systems that will not move or damage when leaned on or bumped into by operators.

4. Service Access: Lamps shall be easily replaceable from inside the air-handling unit.

   a. Install access door(s) with window to access UV light. Treat each window and test to confirm UV emitted through the window is below the threshold limits of NIOSH and ACGIH.
   b. If adequate space is unavailable inside air-handling unit, install UV-C lamp systems on a slide out rail to allow lamp replacement from one exterior side of air-handling unit.

5. Factory wire UV-C lamp systems internally and terminate at a disconnecting switch on the exterior of the air-handling unit casing.

   a. Switch to include a lock-out/tag-out feature.
   b. In addition to disconnecting switch, provide each access door accessible to UV-C lamp systems with a positon limit switch wired into UV-C lamp systems power circuit to de-energize power to UV-C lamp systems when door is opened.

6. Install a caution nameplate at each UV-C lamp systems disconnecting switch that reads: "DANGER, UV LIGHTS - Turn off before entering."
7. Protection from UV Damage: Materials in direct or indirect (reflected) contact with UV shall be tested and certified as UV tolerant. Any material not certified shall be completely shielded from UV using a certified UV-tolerant material such as metal. UV tolerance shall be capable of performing intended duty for a minimum of [**20**] <**Insert number**> years.
8. Shipping: Remove UV-C lamps after factory testing; package and ship UV-C lamps in protective containers for field installation.

   a. Label exterior of enclosures with detailed description of container contents, including air-handling unit designation.
   b. Ship UV-C lamps for each air-handling unit in separate containers.

H. UV-C Lamp System Irradiance Monitoring:

1. Sourcing: Furnished by UV-C lamp system manufacturer with UV-C lamp systems.
2. General: UVGI monitoring consisting of sensor(s) and controller to measure and locally display UV output irradiance in [**absolute output (microwatts/sq. cm)**] [**and**] [**user-defined percentage of relative output**].
3. Measurement Range: Suitable for highest measured irradiance encountered by application, but not less than [**10,000**] [**20,000**] <**Insert value**> microwatts/sq. cm.
4. NIST traceable calibration.
5. Remote Monitoring Signal: 4- to 20-mA output signal for remote monitoring.

I. UV-C Lamp System Status Monitoring:

1. Sourcing: Furnished by UV-C lamp system manufacturer with UV-C lamp systems.
2. Monitors operating status of UV-C lamps by measuring change in electrical current.
3. On/off status of lamps displayed by LED lights on face of local display unit.
4. Remote Monitoring Signal: On/off status relays for remote monitoring.

2.34 HEAT WHEELS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain heat wheels from single source from single manufacturer.

C. Performance:

1. Heat wheels shall be engineered by manufacturer to provide a highly reliable, low-maintenance product for use under continuous operation over an extended operating period of not less than [**20**] [**25**] <**Insert number**> years. Provide supporting documentation if requested to show how features of product design comply with performance indicated.
2. Products with ratings that exceed indicated pressure drop, fall short of sensible and latent recovery performance indicated, or transfer contaminants in excess of requirements indicated are unacceptable and should not be submitted for review and approval.
3. Fully-assembled and -installed heat wheel shall be suitable for use in air systems that supply air to tenant occupied space and shall comply with NFPA 90A and governing building codes.

D. Testing and Certification:

1. Thermal Performance: Certification by a qualified independent testing organization documenting the following:

   a. Sensible and latent recovery efficiencies conducted in accordance with ASHRAE 84 with results presented in accordance with ASHRAE 84 and AHRI 1060 (I-P) and AHRI 1061 (SI).
   b. Sensible, latent, and pressure loss performance over a range of operating points as required by ASHRAE 84 and specifically for actual airflow conditions required by Project.

2. Cross Contamination: Cross-contamination performance reports to validate compliance with requirements indicated.

   a. Independent test report shall document desiccant-coated transfer media exhibits [**3**] [**or**] [**4**] Angstrom behavior and does not transfer pollutants typically encountered in indoor air environment having room operations and functions indicated.
   b. Testing shall be performed in a test facility complying with ASHRAE 84 for tracer gas testing.
   c. Challenge gases used for testing shall include chemicals that represent contaminates typically encountered and include at least the following: acetaldehyde, methanol, methyl isobutyl ketone, propane, and xylene <**Insert contaminate**>.

3. Flame and Smoke: NRTL test report listing flame-spread index and smoke-developed index of media when tested in accordance with ASTM E84 to comply with requirements indicated.
4. Microbial Resistance: Test report documenting ability of wheel faces and transfer media to actively limit microbial growth.

a. Testing completed by a qualified research institution or testing laboratory using common live bacterial cultures to document antimicrobial performance with 95 percent mortality effectiveness.

5. Corrosion Resistance: Test report summarizing acid-resistance effectiveness of media face coating completed in accordance with ASTM corrosion-test methodologies.

E. Rotors:

1. Construct rotor media of aluminum base material pre-coated with a desiccant before forming into honeycomb media structure consisting of circular spiral layers.
2. Aluminum base material shall be at least [**0.0015 inch**] <**Insert dimension**> thick before coating.
3. Media layers shall be joined together using adhesive to bond between flat and corrugated media layers.
4. Media Coating:

a. Coat media surfaces with a nonmigrating solid adsorbent desiccant layer before forming into the structure to ensure that all surfaces are coated.
b. Desiccant coating shall be inorganic and use a [**3**] [**or**] [**4**] Angstrom molecular sieve to achieve desired [**3**] [**or**] [**4**] Angstrom selectivity, excluding contaminants larger than [**3**] [**or**] [**4**] Angstroms while effectively transferring water vapor.
c. In addition to desiccant coating applied to aluminum substrate, cover two faces of rotor with a two-part polymer coating specifically chosen for chemical resistance and corrosion protection. Coating shall be selected to provide life expectancy indicated when exposed to airstreams encountered.
d. Media exposed to airstream shall exhibit effective antimicrobial action to protect against development and spread of microbial contaminants.
e. Rotor media with applied coatings and adhesive shall have a flame-spread index of [**0**] <**Insert value**> and a smoke-developed index of [**5**] <**Insert value**> when tested in accordance with ASTM E84.

5. Media depth shall be determined by heat wheel manufacturer to achieve performance indicated.
6. Media shall not transfer pollutants typically encountered in an indoor air environment having room operations and functions indicated.
7. Media shall be cleanable without degrading performance over time.
8. Dry particles up to 800 microns shall pass freely through the media.
9. Provide segmented rotor media to allow for field installation and replacement of one section at a time without requiring side access. Removal and replacement shall be made while facing rotor media face.
10. Rotor media shall be held in place by a rigid structural spoke system made of extruded aluminum.
11. Coat exposed surfaces of aluminum spoke system for corrosion protection.
12. Rotor structural spoke system shall be designed and manufactured to provide for field installation of media without possibility of media deformation or misfit.
13. Media shall be secured within structural spoke system by mechanical means, relying on a formed friction fit without use of adhesives or silicone.
14. Rotors that cannot be installed in air-handling units as a single complete factory assembly coming from heat wheel manufacturer shall be remotely assembled by trained factory service personnel that are employed by heat wheel manufacturer.

F. Purge Sector:

1. Factory-set, field-adjustable purge sector designed to limit cross contamination to less than [**0.04**] <**Insert number**> percent of that of exhaust airstream concentration into supply airstream.
2. Factory-set, field-adjustable purge sector designed to eliminate cross contamination of exhaust airstream into supply airstream.

G. Seals:

1. Maintenance-free "non-contact" type to eliminate wear, excessive drag, and resulting added horsepower required for motor drive system, while still being capable of resisting high-pressure differences.
2. Equip rotor with labyrinth seals, which at no time shall make contact with any rotating surface of rotor face.

   a. Seals shall be field adjustable and set to within factory-specified tolerances.
   b. Provide multipass seals with four labyrinth stages for optimum performance or alternative design with documented test results showing comparable performance.

3. Seal shall be secured to housing either by an extruded-aluminum strip with adjustment slots for fastening bolts to the casing frame or by using adjustable clips. Clips shall be made of stainless steel or other noncorrosive material to resist corrosion and possible damage to transfer media.

H. Shafts:

1. Shaft supporting rotor between bearings shall be one piece, solid steel, accurately turned, ground, polished, and ring gauged for accuracy.
2. Machine and polish shaft within bearing contact area to comply with bearing manufacturer's written recommended tolerances.
3. Use a dial indicator to inspect shafts for roundness and straightness.
4. Coat exposed surfaces of shaft with a corrosion-inhibitive coating.
5. Shaft shall be machined to provide a shoulder against bearings for a positive locked position to eliminate any lateral movement of rotor due to axial bearing loads.

I. Bearings:

1. Support rotor shaft by two pillow block [**tapered roller**]bearings designed for an ABMA 11 L-10 life of at least [**200,000**] [**1,000,000**] hours.
2. Bearings shall be maintainable and replaceable without removal of rotor from its casing or media from spoke support system.
3. Grease fittings for each bearing shall be easily accessible and within view of bearing.
4. Reverse Rotation: Clutch bearing and extended shaft, or equivalent alternative, to prevent reverse rotation and ensure that wheel can only rotate in direction commensurate with effective purge operation.

J. Frame and Housing:

1. Design frame to limit deflection of rotor due to air pressure loss to less than [**0.03125 inch**] <**Insert deflection**>, [**as measured at the outer radius, during maximum rated**

airflow condition]when exposed to a wheel pressure differential of [**25**] <**Insert number**> percent above design conditions.

2. Construct rigid frame of welded structural [**aluminum**] [**galvanized steel**] [**painted steel**] [**or**] [**stainless steel**].
3. Designed and manufactured in one, two, or more sections as required by application to provide a rigid structure, when completely assembled, capable of supporting rotor.

    a. For horizontal airflow applications, support rotor at each end only with no additional support under center.
    b. For vertical airflow applications, provide one additional bottom center support.
    c. Clearly mark each section of multiple section units for easy installation.

4. Construct housing of [**galvanized-steel**] [**painted steel**] [**aluminum**] [**or**] [**stainless steel**] formed sheets designed to prevent corrosion.
5. Housing shall be reinforced as required to provide a solid mounting surface of peripheral and radial seals, to maintain a fixed distance between rotor surface and any housing part.
6. There shall be no special requirement to provide air-handling unit casing side access for future rotor removal and service. All rotor service shall be performed from inside air-handling unit at face of rotor.
7. Requirements for Painted Frame and Housing:

    a. Comply with painting manufacturer's written preparation and application requirements.
    b. Treat galvanized steel that is not phosphatized with a phosphate rinse to ensure that paint adheres.
    c. Apply rust-inhibiting primer before applying finishing coats.
    d. Apply multiple coats to achieve dry film thickness required for protection indicated.
    e. Finish coat color to be [**manufacturer's standard**] <**Insert color**>.
    f. Painted products shall have no deterioration when subjected to the following:

        1) Salt spray test in accordance with ASTM B117 with 5 percent salt solution fog at 95 deg F for a period of [**500**] [**1000**] [**2000**] <**Insert number**> hours.
        2) Acid-resistance test in accordance with ASTM D3260 with 15-minute exposure to 10 percent hydrochloric acid at room temperature.

K. Motor and Drive Assembly:

1. Motor Enclosure: Totally enclosed.
2. Motor nameplate horsepower shall exceed maximum load of driven assembly.
3. Multiple belt-drive assembly shall be automatically tensioned and arranged to eliminate any side-to-side movements and slippage.
4. Motor and drive assembly shall be easily accessible and visible for inspection and maintenance.
5. Drive assembly, except motor, shall have a life expectancy of [**45,000**] [**90,000**] <**Insert number**> hours.

L. Variable-Frequency Controller:

1. Variable-speed control of rotor through a variable-frequency controller.
2. Digital programming with a manual-speed adjustment on the front face of controller.

3. Rotor drive system shall allow for a turndown ratio of 80:1 (20 to 0.25 rpm).
4. Controller with switchable control either locally on front of controller or remotely by a control system.
5. Controller with a motor-rated disconnect switch or circuit breaker having a withstanding rating greater than that required by field electrical power system, but not less than [**42,000**] [**65,000**] <**Insert value**> A.
6. Controller mounted in a NEMA 250, [**Type 1**] [**Type 4**] [**Type 4X**] [**or**] [**Type 12**] enclosure.

M. Rotation Sensor: Proximity-type rotation sensor and target to provide [**rotational speed (rpm) analog signal and**]wheel stop digital alarm signal for interface to remote-control system.

N. Monitoring and Control:

1. Single-Source Responsibility: Heat wheel manufacturer shall provide a complete monitoring and control package for heat wheel with controller, local display, operator interface, sensors, switches, transmitters, accessories, components, devices, and programming for a complete and operating heat wheel to ensure that responsibility for heat wheel and its operation resides with one source.
2. Enclosure:

   a. House controller and control devices in a NEMA 250, [**Type 1**] [**Type 4**] [**Type 4X**] [**or**] [**Type 12**] enclosure.
   b. Enclosure with LCD screen to allow viewing and changing parameters.
   c. Enclosure with full front face hinged door and lockable handle.
   d. Air-handling unit manufacturer shall mount enclosure of outside of air-handling unit casing in vicinity of heat wheel.

3. DDC with the following:

   a. Conversion of temperature and relative humidity readings into grains, dew point, and enthalpy.
   b. Calculation and reporting of real-time unit effectiveness.
   c. Calculation and reporting of accumulation of energy (Btu) recovered over time.
   d. With user input of energy costs, calculation and accumulation of dollars saved over time.
   e. An alarm output if wheel is not rotating and not rotating in correct direction.
   f. Programming for integration of enthalpy-based summer-winter change over, frost prevention, and supply temperature control such that they also function correctly as the wheel speed is modulated.
   g. Communications and data transfer for remote monitoring and control through ASHRAE 135 (BACnet) interface.
   h. Option to achieve conversion and calculations indicated is for heat wheel manufacturer to employ building controls provider, to provide a field-installed DDC with LCD to be mounted directly adjacent to heat wheel manufacturer monitoring and control enclosure.

4. Four, field-mounted, high-precision dry-bulb temperature and either wet-bulb temperature or humidity sensors shall be provided by heat wheel manufacturer to air-handling unit manufacturer for factory mounting in accordance with heat wheel

manufacturer's written instructions to measure dry-bulb temperature and either wet-bulb temperature or humidity at each of four energy wheel airstreams.

a. Sensors shall be wired to controller or controller expander board located within enclosure.

5. Wheel Rotation: Rotation detector module to detect a rotating wheel, and correct direction of rotation[**and speed**].
6. Active Monitoring and Control of Purge: Manufacturer's standard method to ensure that proper purge operation is maintained actively in response to changes in system airflows and pressures that normally occurs with a variable-volume system and where pressure changes appreciably due to filter loading and damper modulation.

O. Air-Handling Unit Factory Assembly:

1. Internal Access: Provide each heat wheel with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
2. Removal and Replacement: Each heat wheel shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
3. Drain Pans: In applications capable of formation of frost, install condensate drain pans to collect and drain water to exterior of air-handling unit casing.
4. Supports for Heat Wheel:

a. Construct a freestanding and self-supporting structural framework to support each heat wheel individually from and independent of adjacent heat wheels.
b. Construct frame work from aluminum [**galvanized-steel**]or stainless steel[**structural shapes**].

5. Comply with heat wheel manufacturer's written installation instructions.

2.35 FIXED PLATE HEAT EXCHANGERS

A. Fixed Plate Sensible Heat Exchangers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain heat exchangers from single source from single manufacturer.
3. Description: A device for purpose of transferring only sensible energy from one airstream to another with no moving parts. Design may incorporate parallel, cross-or counterflow construction or a combination of these to achieve the energy transfer.
4. Performance: Indicated on Drawings with no cross contamination between exhaust and supply airstreams.

a. Maximum Pressure Differential: Suitable for maximum [**6 inches wg**] <**Insert pressure**>.
b. Maximum Temperature: Suitable for maximum [**194 deg F**] <**Insert temperature**>.

5. Casing: [**Aluminum**] [**Galvanized steel**] <**Insert material**>.
6. Plates: Evenly spaced, sealed, and arranged for [**counter**] [**cross**] airflow.

a. Plate Material: [**Embossed aluminum**] [**Stainless steel**] [**High-density plastic**] <**Insert material**>.
b. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating. See Drawings for heat exchangers requiring a corrosion-resistant coating.
c. Aluminum Plate Coating: [**None**] [**Epoxy**] <**Insert coating**>. See Drawings for heat exchangers requiring a corrosion-resistant coating.

B. Fixed Plate Total Heat Exchangers:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain heat exchangers from single source from single manufacturer.
3. Description: A device for purpose of transferring total energy (sensible and latent) from one airstream to another with no moving parts. Design may incorporate parallel, counterflow construction to achieve the energy transfer.
4. Performance: Indicated on Drawings with no cross contamination between exhaust and supply airstreams.

a. Maximum Pressure Differential: Suitable for maximum [**6 inches wg**] <**Insert pressure**>.
b. Maximum Temperature: Suitable for maximum [**194 deg F**] <**Insert temperature**>.

5. Casing: [**Aluminum**] [**Galvanized steel**] <**Insert material**>.
6. Plates: Evenly spaced, sealed, and arranged for counter airflow.

a. Plate Material and Coating: Chemically treated paper, or polymer on [**aluminum**] <**Insert material**>, with selective hydroscopicity, moisture permeability, and gas barrier properties.

C. Air-Handling Unit Factory Assembly:

1. Internal Access: Provide each fixed plate heat exchanger with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
2. Removal and Replacement: Each fixed plate heat exchanger shall be independently removable and replaceable through a removable access panel or door installed in air-handling unit casing.
3. Drain Pans: In applications capable of formation of frost, install condensate drain pans to collect and drain water to exterior of air-handling unit casing.
4. Supports for Fixed Plate Heat Exchanger:

a. Construct a freestanding and self-supporting structural framework to support heat exchangers.
b. Construct frame work from aluminum[**, galvanized-steel,**] or stainless steel[**structural shapes**].

5. Comply with fixed plate heat exchanger manufacturer's written installation instructions.

2.36 HEAT PIPE HEAT EXCHANGERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain heat exchangers from single source from single manufacturer.

C. Description: Air-to-air energy recovery heat exchanger employing tubes charged with a fluid for purpose of transferring sensible energy from one airstream to another through the vaporization of fluid.

D. Performance: Indicated on Drawings with no cross contamination between exhaust and supply airstreams.

E. Certification: Rated[**, listed and labeled**] in accordance with AHRI 1060 (I-P) and AHRI 1061 (SI).[**NRTL listed in accordance with UL 207.**]

F. Casing and Tube Sheets: [**Galvanized-steel**] [**or**] [**stainless steel**] flanged casing minimum [**16 gauge**] <**Insert thickness**> thick, with airtight [**single**] [**double**] [**foam-filled double**] partition between exhaust and supply airstreams.

G. Fluid in Sealed Tubes: Selected by heat pipe heat exchanger manufacturer and classified as Safety Group A1 in accordance with ASHRAE 34.

H. Tubes:

1. Tube Diameter: Selected by heat pipe heat exchanger manufacturer; not less than nominal1/2 inchand not more than nominal 1 inchindiameter.
2. Tube Material: [**Aluminum**] [**or**] [**copper**] <**Insert material**>; minimum thickness required for fluid pressure and temperature encountered.
3. Number of Tube Rows: As required by performance; not to exceed [**8**] <**Insert number**>.

I. Fins: [**Aluminum**] [**or**] [**copper**] <**Insert material**>.

1. Fin Configuration: [**Extruded**] [**plate**] [**or**] [**spiral**].
2. Fin Spacing: As required by performance; not to exceed12 fins per inch.
3. Fin and Tube Bond: [**Mechanical expanded into collared fins and tube sheets**] [**Silver brazed**].

J. Coating: [**None**] [**Flexible epoxy polymer E-coating**] [**Baked phenolic**] <**Insert coating**>; apply to supply and exhaust.

K. Control: Integral plenum containing heat pipe coil and gasketed, face-and-bypass, opposed-blade dampers with rods extended outside casing for damper operator and linkage.

L. Control: Pivot center of bottom of heat pipe coil on shaft and bearings to tilt coil. Include tilt controls with electronic controller, electric actuator and linkage, thermostats, sensors, and polyester-fabric-coated flexible connector for automatic supply temperature regulation, summer/winter changeover, and frost protection.

M. Air-Handling Unit Factory Assembly:

1. Internal Access: Provide each heat pipe heat exchanger with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
2. Removal and Replacement: Each heat pipe heat exchanger shall be independently removable and replaceable through a removable access panel installed in air-handling unit casing.
3. Drain Pans: In applications capable of formation of frost, install condensate drain pans to collect and drain water to exterior of air-handling unit casing.
4. Supports for Heat Pipe Heat Exchanger:

    a. Construct a freestanding and self-supporting structural framework to support each heat pipe heat exchanger individually from and independent of adjacent heat pipe heat exchangers.
    b. Construct frame work from aluminum[**, galvanized-steel,**] or stainless steel[**structural shapes**].

5. Comply with heat pipe heat exchanger manufacturer's written installation instructions.

2.37 AIR BLENDERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

B. Source Limitations: Obtain blenders from single source from single manufacturer.

C. Description: Static air mixing devices fabricated in assemblies consisting of multidirectional vanes that are designed to reduce stratification of multiple mixed airstreams and improve uniformity of the air tunnel velocity profile located downstream of air mixer.

D. Performance:

1. Certification: Documented performance verified by tests performed by an independent agency [**or**] [**factory tests witnessed by a professional engineer that is not a company employee**].
2. Mixing: Uniform mixed airstream within [**6 deg F**] <**Insert temperature**> of the theoretical average temperature of two or more airstreams.
3. Indicated on Drawings.

E. Construction:

1. Configuration: Indicated on Drawings.
2. Material: [**Aluminum**] [**galvanized steel**] [**Type 304 stainless steel**] [**or**] [**Type 316 stainless steel**].
3. Thickness: [**0.080 inch**] [**0.125 inch**] <**Insert dimension**>.
4. Attachment: Integral mounting flange for attachment to mounting substrate.
5. Welding: Stitch or continuous welds. Filler metals matched to welded materials.
6. Hardware: [**Stainless**] [**Zinc-plated carbon**] steel.
7. OEM Factory Assembly: Single-piece assembly for sizes through 96 inches. For larger sizes, air mixers shall be fabricated in two pieces, bolted together to ensure proper fit and alignment and then dissembled for shipment.
8. Finish: [**Anodized**] <**Insert requirements**>.

F. Air-Handling Unit Factory Assembly:

1. Internal Access: Provide each air mixer with internal access from [**downstream**] [**and**] [**upstream**] sides as indicated on Drawings.
2. Install air mixer assemblies in an internal separating wall reinforced to limit deflection to [**L/200**] <**Insert value**> when subjected to a horizontal force of [**200 lb**] <**Insert value**> at any point on the air mixer assembly.
3. Blank-off and seal assembly to prevent leakage and air bypass around air mixer.
4. Operating Clearance: Maintain upstream and downstream operating clearances in accordance with manufacturer's written installation requirements.

2.38 AIR-HANDLING UNIT FACTORY DRAIN PIPING AND PIPING INSULATION

A. General:

1. Air-handling unit manufacturer to factory install piping inside air-handling units.
2. If more than one material is listed, material selection is by air-handling unit manufacturer.

B. Aluminum Piping:

1. Pipe: Aluminum ASTM B241/B241M, Grade 1061, Temper T6, seamless longitudinal joins with beveled or plain ends; and wall thickness as indicated under applications.
2. Fittings: Cast aluminum, ASTM B26/B26M, Grade 356, Temper T6, ASME B16.1 Class 150; threaded ends.
3. Flanges: Cast aluminum, ASTM B26/B26M, Grade 356, Temper T6, ASME B16.1, Class 150 including bolts, nuts, washers, and gaskets of the following end connections and facings:

    a. Threaded end connections for threaded joints, welding-neck with butt-joint for welded joints, and blinds for use with flanged joints requiring close-off.

4. Unions: Cast-aluminum, ASTM B26/B26M, Grade 356, Temper T6, hexagonal-stock body; female NPT threaded ends.

C. Copper Tubing:

1. Tubing: Drawn temper, [**ASTM B88, Type L**] [**ASTM B88, Type M**] [**or**] [**Type DWV in accordance with ASTM B306**].
2. Fittings: Wrought-copper and copper-alloy, ASME B16.22, pressure fittings.
3. Unions: Cast-copper-alloy, MSS SP-123, hexagonal-stock body; female NPT threaded ends
4. Solder Filler Metals: ASTM B32, lead-free alloys, and water-flushable flux in accordance with ASTM B813.

D. Stainless Steel Piping:

1. Pipe: ASME B36.19/ASME B36.19M, stainless steel ASTM A312/A312M, with beveled or plain ends; seamless [**or welded**]longitudinal joints, Grade TP316L, and wall thickness as indicated under applications.

2. Fittings, Threaded: MSS SP-114, Class 150, stainless steel ASTM A351/A351M, Grade CF8M.
3. Fittings, Welded: ASME B16.9, stainless steel ASTM A403/A403M, Grade WP316L, seamless, wall thickness to match adjoining pipe.
4. Flanges: Stainless steel ASTM A182/A182M, Grade F316L, ASME B16.5, Class 150 including bolts, nuts, washers, and gaskets of the following material group, end connections, and facings:
    a. Material Group: 2.2.
    b. Threaded end connections for threaded joints, welding-neck with butt-joint for welded joints, and blinds for use with flanged joints requiring close-off.
5. Unions: MSS SP-114, Class 150, stainless steel ASTM A351/A351M, Grade CF8M; female NPT threaded ends.

E. Floor Drain Piping:

1. [**Schedule 40**] <**Insert pipe schedule or wall thickness**> aluminum or stainless steel pipe with threaded ends [**or**] [**copper tube with soldered threaded male adapters**].
2. Factory install a dedicated drain pipe for each floor drain and extend pipe to access side of air-handling unit.
    a. Terminate pipe with a threaded pipe cap [**3 inches**] <**Insert dimension**> beyond exterior face of air-handling unit casing. Threaded pipe cap material to match pipe material.
    b. Pipe size to match size of floor drain connection.

F. Fan Drain Piping:

1. [**Schedule 40**] <**Insert pipe Schedule or wall thickness**> aluminum or stainless steel pipe with threaded ends [**or**] [**copper tube with soldered threaded male adapters**].
2. Factory install a dedicated drain pipe for each housed centrifugal fan with a drain connection and extend pipe to access side of air-handling unit.
    a. Terminate pipe with a threaded pipe cap [**3 inches**] <**Insert dimension**> beyond exterior face of air-handling unit casing. Threaded pipe cap material to match pipe material.
    b. Install a twin sphere [**EPDM**] [**or**] [**neoprene**] pipe connector in the pipe between the fan connection and the pipe penetration through the air-handling unit casing.
    c. Pipe size to match size of fan drain connection.
    d. Install a threaded union or thread-on flange in drain pipe at connection to fan.

G. Drain Pan Piping:

1. [**Schedule 40**] <**Insert pipe schedule or wall thickness**> aluminum or stainless steel pipe with threaded ends [**or**] [**copper tube with soldered threaded male adapters**].
2. Factory install drain piping for drain pan(s). Install a dedicated drain pipe for each drain pan serving different air-handling unit internal components. Where multiple drain pans serve like components interconnect drain piping to a single drain pipe for field connection.

a. Where interconnecting cooling coil condensate drain pans from upstream and downstream sides of cooling coil, provide pipe with a water seal trap configured to prevent air bypass.
b. Terminate pipe with a threaded pipe cap [**3 inches**] <**Insert dimension**> beyond exterior face of air-handling unit casing. Threaded pipe cap material to match pipe material.
c. Drain pipe size to match size of drain pan connection.

H. Piping Insulation:

1. Factory insulate bottom cooling coil drain pan pipe with [**1-inch-**] <**Insert dimension**> thick, flexible elastomeric insulation where pipe is located under and outside of the air-handling unit casing but within the air-handling unit base.
2. Factory insulate steam and steam condensate piping located inside of air-handling with [**2-inch-**] <**Insert dimension**> thick, preformed mineral-fiber pipe insulation.
3. Cover pipe insulation with a factory-applied aluminum or stainless steel jacket.

2.39 DRAINS

A. Floor Drains:

1. Drain Body: Fabricate floor drain body of NPS 4or larger aluminum or stainless pipe and weld a plate of same material to the bottom. Option to fabricate an aluminum or stainless steel rectangular box drain at least 4 by 4 inches0.1 inch (3 mm) thick.
2. Drain Connection: Weld a nominal [**NPS 2**] <**Insert pipe size**> half coupling in side of drain body located within1 inch from bottom.
3. Drain Cover: Perforated plate, at least0.1 inch (3 mm) thick, or grating, fabricated from aluminum or stainless steel. Drain cover shall be supported and secured in place by drain body, but not fastened to drain body with fasteners.
4. Fluid Seal: [**Seal**] [**Weld**] floor drain body to air-handling unit floor for a watertight installation.
5. Mounting: Recess floor drain body into structural base. Top of floor drain to be slightly recessed below air-handling unit finished floor for unobstructed gravity flow from floor into drain.
6. Application: Install floor drains in air-handling unit floors at locations indicated on Drawings.
7. Application: Install floor drains in air-handling unit floors of all sections.
8. Application: Install floor drains in air-handling unit floors of [**coil**] [**coil and humidifier**] [**coil, heat wheel, heat exchanger, humidifier**] [**potentially wet**] <**Insert floor drain locations**> sections and associated access sections.

2.40 FACTORY ASSEMBLED ELECTRICAL

A. Factory install [**UV-C and switches**,] [**service light fixtures and switches,**] [**and**] [**receptacles**] for each air-handling unit.

1. Locate in a convenient and field-accessible location.
2. Installation shall comply with NFPA 70.
3. Wire, Conduit, and Enclosures:

a. Minimum Conduit Size: [**3/4 inch**] <**Insert dimension**>.
b. Materials: [**Metal, with a corrosion-resistant finish**] [**Aluminum or stainless steel**] [**Stainless steel**].
c. Supports: Support conduits, boxes, and enclosures using corrosion-resistant fastening hardware[**constructed of stainless steel**].
d. Conduit: Locate conduit inside the air-handling unit casing. Conduit installed on exterior of air-handling unit casing is unacceptable.
e. Wire:

1) Copper, rated for 600 V, solid wire for size [**No. 10 AWG**] <**Insert wire size**> and smaller and stranded wire for larger sizes.
2) Minimum Wire Size: [**No. 12 AWG**] <**Insert wire size**>.
3) Each circuit shall have a ground wire.
4) Install wire in conduit.

f. Boxes, Conduit Outlet Bodies, and Enclosures:

1) Located in Airstream: NEMA 250, [**Type 4**] [**Type 4X**] [**or**] [**Type 12**] <**Insert Type**>.
2) Located on Exterior of Air-handling Unit Casing: NEMA 250, [**Type 1**] [**or**] [**Type 12**] <**Insert Type**>.

g. Seals: Seal pathways to prevent air leakage between air-handling unit exterior and interior, and between internal component sections.
h. UV-C Lamp System Applications: Wire all UV-C lamp systems located in the same air tunnel to a single circuit.
i. Service Lighting Applications:

1) Provide quantity of 20-A branch circuits required to power service light fixtures.
2) For air-handling units consisting of multiple stacked tiers, provide separate circuits for top and bottom tiers of air-handling units.
3) Factory install a [**main disconnect switch**] [**field power junction box**] for interfacing air-handling power for service lighting with single-point field power wiring connection.

j. Receptacle Applications:

1) For air-handling units consisting of multiple stacked tiers, provide separate circuits for top and bottom tiers of air-handling units.
2) Factory wire receptacles to a [**main disconnect switch**] [**field power junction box**] for interfacing air-handling power for receptacles with a single-point field power wiring connection.

B. Main Disconnect Switches: Factory-install main disconnect switch mounted on air-handling unit casing exterior for interface of factory power wiring with field power wiring.

1. Specification Grade; "Heavy Duty Type"; "quick-make," "quick-break" construction.
2. Three pole, [**fused**] [**or**] [**nonfused**].
3. 600 V rated.

4. Minimum Short-Circuit Current Rating: As required by electrical power distribution system, but not less than [**42,000**] [**65,000**] <**Insert value**> A.
5. Enclosure: NEMA 250, [**Type 1**] [**Type 12**] <**Insert Type**>.
6. Operating handle shall be of box-mounted type that directly drives switch mechanism.
7. Disconnect switch shall use a flange-operated visible blade that is close coupled to a vertical-lift-type handle that achieves a positive visible indication of disconnect with cover open or closed.
8. Disconnect switch shall have a defeatable, front-accessible, mechanical interlock to prevent opening of cover when switch is in "ON" position, and to prevent turning switch "ON" when the door is open.
9. Include a solid neutral as required by authorities having jurisdiction.
10. Disconnect switch shall have a ground lug for ground wire termination.
11. Operating handle shall be lockable in open position.
12. Horsepower rated.
13. Feed through or double lugged.

C. Field Power Junction Box: Factory-install junction box with internal wire terminal block mounted on air-handling unit casing exterior for interface of factory power wiring with field power wiring.

D. Service Light Fixtures:

1. Fluorescent Luminaires:

a. Basis-of-Design Product: Subject to compliance with requirements, <**Insert manufacturer's name; product name or designation**>.
b. Suitable for wet locations and operation in cold- and hot-temperature extremes encountered; dust and moisture resistant.
c. High-impact, UV-stabilized fiberglass-reinforced polyester housing, high-impact acrylic lens.
d. Two, cool white, T [**5**] [**5HO**] [**8**] [**8HO**] lamps, and an electronic ballast.

2. LED Luminaires:

a. Basis-of-Design Product: Subject to compliance with requirements, <**Insert manufacturer's name; product name or designation**>.
b. Suitable for wet locations and operation in cold- and hot-temperature extremes encountered; dust and moisture resistant.
c. High-impact, UV-stabilized fiberglass housing and acrylic lens.
d. Light Color: [**3500**] [**4000**] [**5000**] K.
e. Light Output: [**2000**] [**3000**] [**4000**] lumens.
f. Driver: 1 percent dimming.

3. Vaportight Fixtures:

a. Basis-of-Design Product: Subject to compliance with requirements, <**Insert manufacturer's name; product name or designation**>.
b. Suitable for wet locations and operation in cold- and hot-temperature extremes encountered; dust and moisture resistant.
c. Cast aluminum housing and guard with heat-resistant, tempered, clear glass globe.
d. Incandescent Lamps: [**150**] [**200**] [**300**] W.

e. LED A21 Series Lamps:

1) Light Color: [**3000**] [**5000**] K.
2) Light Output: [**1700**] <**Insert value**> lumens.

4. Application: Provide service light fixtures where indicated on Drawings.
5. Application: Provide one service light fixture in each accessible section of air-handling units.
6. Application: Provide one service light fixture in fan[**, coil**] [**filter**] <**Insert section**> sections of air-handling units.

E. Toggle Switches for Service Light Fixtures:

1. Single-Pole Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
2. Two-Pole Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
3. Three-Way Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
4. Four-Way Switches, 120/277 V, 20 A: Comply with UL 20 and FS W-S-896.
5. Lighted Single-Pole Switches, 120/277 V, 20 A: Comply with NEMA WD 1, UL 20, and FS W-S-896.

a. Description: Handle illuminated when switch is on.

6. Toggle Switch Box and Cover: Mount toggle switch in a [**metal**] [**cast-aluminum**] outlet box with [**cast-aluminum**] [**or**] [**stainless steel**] cover.
7. Application: Factory install service light switches at locations indicated on Drawings.
8. Application: Factory install a single service light switch to switch all service light fixtures from a single location.
9. Application:

a. Factory install a service light switch for each service light fixture or group of service light fixtures accessible from a single access door adjacent to the access door.
b. Factory install switching configuration (single, three way, or four way) required to operate a single service light fixture or group of service light fixtures from any access door that opens to respective service light fixtures.

10. Switches with Lighted Handles Applications: Lighted handle feature may be omitted where on/off status of internal lights can be viewed through an access door window.

F. Receptacles:

1. Isolated-Ground Duplex Receptacles, 125 V, 20 A:

a. Description: Straight blade; equipment grounding contacts shall be connected only to green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts. Two pole, three wire, and self-grounding.
b. Configuration: NEMA WD 6, Configuration 5-20R.
c. Standards: Comply with UL 498 and FS W-C-596.

2. Duplex GFCI Receptacles, 125 V, 20 A:

a. Description: Integral GFCI with "Test" and "Reset" buttons and LED indicator light. Two pole, three wire, and self-grounding.
b. Configuration: NEMA WD 6, Configuration 5-20R.
c. Type: Non-feed through.
d. Standards: Comply with UL 498, UL 943 Class A, and FS W-C-596.

3. Receptacle Box and Cover: Mount receptacle in a [**metal**] [**cast-aluminum**] outlet box with [**cast-aluminum**] [**or**] [**stainless steel**] cover.
4. Applications: Factory install a receptacle in a convenient and field-accessible location on air-handling unit exterior of casing [**at locations indicated on Drawings**] [**near access doors accessing fans**] [**near access doors accessing electric heaters and fans**] [**near access doors accessing energy wheels and fans**] [**near access doors accessing electric heaters, energy wheels, and fans**] <**Insert locations**>.

G. Power Supply to Fan Motors: As indicated on Drawings.

H. Power Supply to Fan Motors: Factory install a [**disconnect switch**] [**junction box**] [**motor controller**] [**variable-frequency controller**] for each fan motor.

1. Locate in a convenient and field-accessible location on unit exterior.
2. Installation shall comply with NFPA 70.
3. Wire, Conduit, and Enclosures:

a. Minimum Conduit Size: [**3/4 inch**] <**Insert dimension**>.
b. Materials: Metal, corrosion resistant[**and constructed of stainless steel**].
c. Motor Termination: Flexible conduit, NRTL listed, not to exceed 36 inches long.
d. Supports: Support conduits, boxes, and enclosures using corrosion-resistant fastening hardware[**constructed of stainless steel**].
e. Wire:

1) Copper, rated for 600 V, solid wire for size [**No. 10 AWG**] <**Insert wire size**> and smaller and stranded wire for larger sizes.
2) Minimum Wire Size: [**No. 12 AWG**] <**Insert wire size**>.
3) Each circuit shall have a ground wire.
4) Install wire in conduit.

f. Boxes, Conduit Outlet Boxes, and Enclosures:

1) Located in Airstream: NEMA 250, [**Type 4**] [**Type 4X**] [**or**] [**Type 12**] <**Insert Type**>.
2) Located on Exterior of Air-Handling Unit Casing: NEMA 250, [**Type 1**] [**or**] [**Type 12**] <**Insert Type**>.

I. Disconnect Switches:

1. Specification Grade; "Heavy Duty Type"; "quick-make," "quick-break" construction.
2. Three pole, [**fused**] [**or**] [**nonfused**].
3. 600 V rated.
4. Minimum Short-Circuit Current Rating: As required by electrical power distribution system, but not less than [**42,000**] [**65,000**] <**Insert value**> A.
5. Enclosure: NEMA 250, [**Type 1**] [**Type 12**] <**Insert Type**>.

6. Operating handle shall be of box-mounted type that directly drives switch mechanism.
7. Disconnect switch shall use a flange-operated visible blade that is close coupled to a vertical-lift-type handle that achieves a positive visible indication of disconnect with cover open or closed.
8. Disconnect switch shall have a defeatable, front-accessible, mechanical interlock to prevent opening of cover when switch is in "ON" position, and to prevent turning switch "ON" when the door is open.
9. Include a solid neutral as required by authorities having jurisdiction.
10. Disconnect switch shall have a ground lug for ground wire termination.
11. Operating handle shall be lockable in open position.
12. Horsepower rated.
13. Feed through or double lugged.

J. Motor Field Power Junction Box:

1. Provide junction box with internal wire terminal block mounted on unit exterior for interface with field power wiring.

    a. Provide for each motor not installed with a factory disconnect or controller with integral disconnect.

2. Factory install internal wiring and conduit to motor.

K. Motor Controllers:

1. NEMA ICS 2, Class A, full-voltage, non-reversing, motor-rated controller.
2. Configured for control of single- or multispeed motors as indicated.
3. Enclosure: NEMA 250, [**Type 1**] [**Type 12**] <**Insert Type**>, with hinged full-front access door with lock and key.
4. Externally Operated[**, Door-Interlocked**] Disconnect: [**Fused disconnect switch**] [**Nonfused disconnect switch**] [**Circuit breaker**] with lockable handle.
5. Short-Circuit Current Rating: As required by electrical power distribution system, but not less than [**42,000**] [**65,000**] [**100,000**] <**Insert value**> A.
6. Hand-Off-Auto Switch: Mounted on face of enclosure.
7. Push-to-Test Run Status Pilot Lights: NEMA ICS 2, heavy-duty type.
8. Control Relays: Time-delay relays.
9. Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.
10. Elapsed-Time Meters: Numerical readout in hours on face of enclosure.
11. Number-of-Starts Counter: Numerical readout on face of enclosure.

L. Variable-Frequency Controllers:

1. Description: NEMA ICS 2; arranged to achieve motor variable speed by adjusting output voltage and frequency.
2. Enclosure: Unit mounted, NEMA 250, [**Type 1**] [**Type 12**] <**Insert Type**>, with hinged full-front access door with lock and key.
3. Externally Operated[**, Door-Interlocked**] Disconnect: [**Fused disconnect switch**] [**Nonfused disconnect switch**] [**Circuit breaker**] with lockable handle.
4. Minimum Short-Circuit Current Rating: As required by electrical power distribution system, but not less than [**42,000**] [**65,000**] [**100,000**] <**Insert value**> A.

5. Technology: Pulse-width-modulation (PWM) output with insulated gate bipolar transistors (IGBT); suitable for variable torque loads.
6. Controller shall consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.
7. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.
8. Output signal shall be programmed to not cause mechanical vibration issues with fan drive assembly.
9. Operating Requirements:

    a. Input AC Voltage Tolerance: [**10**] <**Insert number**> percent.
    b. Input frequency tolerance of 60 Hz, plus or minus 2 Hz.
    c. Capable of driving full motor load, without derating.
    d. Minimum Efficiency: 96 percent at 60 Hz, full load.
    e. Minimum Displacement Primary-Side Power Factor: 95 percent.
    f. Overload Capability: 1.05 times the full-load current for 7 seconds.
    g. Starting Torque: As required by fan and motor drive assembly.
    h. Speed Regulation: 1 percent.
    i. Speed Range: 10:1 speed range.
    j. To avoid equipment resonant vibrations, include critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
    k. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.

10. Controller Adjustability Capabilities: Minimum and maximum output frequency, acceleration and deceleration, and current limit.
11. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or need for replacement:

    a. Surge suppression.
    b. Loss of input signal protection.
    c. Critical frequency rejection.
    d. Overtemperature.
    e. Short circuit at controller output.
    f. Ground fault at controller output. Variable-frequency controller shall be able to start a grounded motor.
    g. Open circuit at controller output.
    h. Input undervoltage.
    i. Input overvoltage.
    j. Loss of input phase.
    k. Reverse phase.
    l. AC line switching transients.
    m. Instantaneous overload, line to line, or line to ground.
    n. Sustained overload exceeding 100 percent of controller rated current.
    o. Starting a rotating motor.
    p. <**Insert features**>.

12. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
13. Automatic Reset and Restart:

a. Capable of multiple restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction.
b. Capable of automatic restart on phase-loss and overvoltage and undervoltage trips.

14. Visual Indication: On face of controller; indicating the following conditions:

a. Power on.
b. Run.
c. Overcurrent and overvoltage.
d. Motor speed (percentage).
e. Various faults with alarm status.
f. Input kilovolt amperes.
g. Power factor.
h. Input kilowatts and kilowatt-hours.
i. Three-phase input and output voltage.
j. Three-phase input and output current.
k. Output frequency.
l. Elapsed operating time (hours).
m. Diagnostic and service parameters.
n. <**Insert conditions**>.

15. Operator Interface: Start-stop and auto-manual selector with manual-speed-control potentiometer.
16. Hardwired Control Signal Interface: A minimum of [**two**] <**Insert number**> analog inputs (0 to 10 V or 0/4 to 20 mA) and [**four**] <**Insert number**> programmable digital inputs.
17. Remote Communication Interface: [**ASHRAE 135 BACnet MS/TP**] [**ASHRAE 135 BACnet IP**] <**Insert requirements**>.
18. Line Conditioning:

a. Input line conditioning.
b. Output filtering.
c. EMI/RFI filtering.

19. Bypass Controller:

a. Bypass Controller/Variable-Frequency Controller Selector Switch: Include manual selector switch on face of enclosure for local operator control of preferred controller.
b. Bypass Mode: [**Manual operation only**] [**Field-selectable automatic or manual**].

1) In automatic mode, include fail-safe control logic to automatically transfer fan motor operation from failed variable-frequency controller to bypass controller.

c. Type: Integrated NEMA ICS 2, Class A, full-voltage, non-reversing, motor-rated controller to operate fan motor if variable-frequency controller is not operational.
d. Arrangement: Configure power supply to bypass controller and variable-frequency controller to completely isolate power to variable-frequency controller while

operating fan motor through bypass controller for safe servicing of variable-frequency controller.

e. Enclosure: Install bypass controller in same enclosure as variable-frequency controller.

f. Remote Monitoring: Include control relay for remote indication of bypass controller operation.

2.41 FACTORY-ASSEMBLED CONTROLS

A. General:

1. Air-handling unit manufacturer shall furnish and factory install control instruments, control power circuit, control transformers, power supplies, wiring, tubing, raceways, and control panels.
2. Provide for a single-point field connection to [**120**] [**277**]-V electrical power for all factory-installed controls. Terminate power connection with a toggle switch mounted in control panel.
3. Control panel shall serve as field tie-in point for all electric damper actuators, and control instruments located within air-handling unit. Controls for control dampers, control valves, and instruments installed in ductwork and piping are not included as part of air-handling unit factory-installed controls.
4. Control instruments shall be installed in accordance with manufacturer's written instructions.
5. Control panel shall house flow, moisture, pressure and temperature transmitters, transformers, dc voltage power supplies, and wiring terminal strip.
6. Carbon dioxide transmitters shall be mounted on air-handling unit casing exterior with sensor port exposed to the airstream.
7. Factory install the following control instruments:

a. Flow station and flow transmitter for each fan.

b. Pressure sensors (inlet and discharge) and one combination pressure differential transmitter, switch, and controller for each filter bank installed in the air-handling unit.

c. Pressure sensor and combination pressure differential transmitter, switch, and controller at the inlet of each fan.

d. Pressure sensor and combination pressure differential transmitter, switch, and controller at the discharge of each fan.

e. Carbon dioxide sensor/transmitters at locations indicated on Drawings.

f. Moisture and temperature sensors and transmitters at locations indicated on Drawings.

g. Temperature switches at locations indicated on Drawings.

h. Control instruments indicated on Drawings.

i. <**Insert requirements**>.

B. Wire and Cable:

1. Single Conductor Control Wiring above 24 V:

a. Wire size shall be at least No. 16 AWG.

b. Conductor shall be 7/24 soft annealed copper stranding with a 2- to 2-1/2-inch lay.

c. Conductor insulation shall be 600 V,Ttype THWN or Type THHN, 90 deg C in accordance with UL 83.
d. Conductor colors shall be black (hot), white (neutral), and green (ground).

2. Single Twisted Shielded Instrumentation Cable above 24 V:

a. Wire size shall be minimum No. 18 AWG.
b. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2-1/2-inch lay.
c. Conductor insulation shall have a Type THHN/THWN or Type TFN rating.
d. Shielding shall be 100 percent 0.35/0.5-mil aluminum/mylar tape, helically applied with 25 percent overlap, and aluminum side in with a No. 18 AWG-7/26 tinned copper drain wire.
e. Outer jacket insulation shall have a 600-V, 90 deg C rating and shall be Type TC cable.
f. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red, and white.

3. Single Twisted Shielded Instrumentation Cable 24 V and Lower:

a. Wire size shall be minimum No. 18 AWG.
b. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2-1/2-inch-lay.
c. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
d. Shielding shall be 100 percent 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with a No. 20-22 AWG tinned copper drain wire.
e. Outer jacket insulation shall have a 300-V, 105 deg C rating and shall be Type PLTC cable.
f. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red, and white.

4. Wire and Cable Installation:

a. Comply with manufacturer's written instructions and NFPA 70.
b. Grounding shall be in accordance with IEEE C2. Ground wire shall be copper. Demonstrate ground resistance.
c. Wiring and cables shall be installed in conduit. Exposed wire and cable are unacceptable.
d. Wire and cables may be grouped in a common raceway, except do not group wires and cables from different voltages.
e. Install control wiring in a separate conduit from power wiring.
f. Wiring shall be continuous from terminal to terminal without splices.
g. Do not install low-voltage wire and cable closer than [**12 inches**] <Insert distance> from line voltage electrical power wire and cables. Provide an installation free of EMI.
h. Use insulated spade lugs for wiring connection to screw terminals.
i. Use shielded cable to transmitters.
j. Terminate wiring and cables within a control panel, within instrument housing, or in a junction box. Clamp the cable over the jacket, in the junction box. Individual

conductors in the stripped section of cable shall be slack between clamping point and terminal block.

k. Terminate wire and cable in control panel with terminal blocks.
l. Identify each wire and cable on each end and at each terminal with a number-coded identification tag. Each wire and cable conductor shall have a unique tag.
m. Perform continuity and meager testing on wiring and cable.

C. Raceways:

1. Conduit:

a. Install wiring and cable in conduit.
b. Minimum Conduit Size: [**1/2 inch**] [**3/4 inch**] <**Insert dimension**>.
c. Materials: Metal, corrosion resistant[**and constructed of stainless steel**].
d. Supports: Support conduits, boxes, and enclosures using corrosion-resistant fastening hardware[**constructed of stainless steel**].
e. Terminations to Actuators and Instruments: Flexible conduit, NRTL listed, not to exceed 24 inches long.

2. Boxes, Conduit Outlet Boxes, and Enclosures:

1) Located in Airstream: NEMA 250, [**Type 4**] [**Type 4X**] [**or**] [**Type 12**] <**Insert Type**>.
2) Located on Exterior of Air-Handling Unit Casing: NEMA 250, [**Type 1**] [**or**] [**Type 12**] <**Insert Type**>.

3. Seals: Seal pathways to prevent air leakage between air-handling unit exterior and interior, and between internal component sections.
4. Conduit Installation:

a. Conduit shall be continuous and secured in a manner that is electrically continuous throughout.
b. Secure threaded conduit entering a cabinet, box, or enclosure with a locknut on outside and on inside, such that conduit system is electrically continuous throughout.

1) Install a metal bushing with insulated throat on inside.
2) Locknuts designed to bite into metal, or on inside of enclosure and shall have a grounding wedge lug under locknut.

c. Conduit box connectors for conduit entering enclosures shall be insulated throat type.
d. Connect conduit with watertight sealing locknuts that are suitable for wet applications.
e. Offset conduits where they enter surface-mounted equipment and panels.
f. Neatly loop and lace wiring installed in panels and other enclosures.
g. Seal conduit runs to prevent the circulation of air by installing seal fittings.
h. Install conduit inside of air-handling unit casing. Wiring and conduit running on exterior of air-handling unit casing is unacceptable.

D. Tubing and Fittings:

1. Products in this paragraph are intended for use with the following:

    a. Main air and signal air to pneumatically controlled instruments, actuators, and other control devices and accessories.
    b. Signal air between pressure instruments, such as sensors, switches, transmitters, controllers, and accessories.

2. Copper Tubing:

    a. Seamless phosphor deoxidized copper, soft annealed or drawn tempered, with chemical and physical properties in accordance with ASTM B75/B75M.
    b. Performance, dimensions, weight, and tolerance in accordance with ASTM B280.
    c. Diameter, as required by application, not less than nominal 0.25 inch.
    d. Wall thickness, as required by application, but not less than 0.030 inch.

3. Copper Tubing Fittings: Brass, compression type.
4. Polyethylene Tubing:

    a. Fire-resistant black virgin polyethylene in accordance with ASTM D1248, Type 1, Class C, and Grade 5.
    b. Tubing shall comply with stress crack test in accordance with ASTM D1693.
    c. Diameter, as required by application, of not less than nominal 0.25 inch.

5. Polyethylene Tubing Fittings: Brass, compression type.
6. Stainless Steel Tubing:

    a. Seamless Type 316 stainless steel, Grade TP, cold drawn, annealed and pickled, free from scale.
    b. Chemical and physical properties in accordance with ASTM A269/A269M.
    c. Diameter, as required by application, of not less than nominal 0.25 inch.
    d. Wall thickness, as required by application, but not less than 0.035 inch.
    e. Furnish stainless steel tubing in [**20-foot**] straight random lengths.

7. Stainless Steel Tubing Connectors and Fittings:

    a. Connectors and fittings shall be stainless steel, with stainless steel collets, flareless type.
    b. Connect instruments to tubing with connectors having compression connector on one end and IPS or NPT thread on other end.

8. Tubing Installation:

    a. Use [**copper**] [**or**] [**stainless steel**] tubing except use fire-resistant polyethylene for tubing located in control panels.
    b. Run tubing parallel to, and at right angles to, casing.
    c. Route multiple runs of tubing in neat parallel lines.
    d. Support tubing as follows:

        1) Support metal tubing with hangers, clips, and tube trays.
        2) Do not use tapes for mounting tubing.

3) Place a support within 1 foot of each change in direction and each branch take-off.
4) Spacing between supports shall not exceed [**60 inches**] <**Insert distance**>.

e. Tubing shall not interfere with access to dampers and equipment or obstruct passageways of any kind.
f. Provide vibration loops in tubing when connecting to equipment that might vibrate.
g. Where joining or mating dissimilar metals where galvanic action could occur, provide dielectric isolation.
h. Make tubing bends with a bending tool. Hard bends, or wrinkled or flattened bends are unacceptable.
i. Install tubing fitting makeup in accordance with manufacturer's written instructions.
j. Do not make tubing connections to a fitting before completing makeup connection.
k. Properly align tubing with fitting. Springing tube into position can result in excessive stress on both tubing and fitting with possible resulting leaks.
l. Do not install fittings close to a bend. Length of straight tubing, not deformed by bending, is required for a proper connection.
m. Check tubing for correct diameter and wall thickness. Tube ends shall be cut square and deburred. Exercise care during cutting to keep tubing round.
n. Wrap threads of fittings with a single wrap of PTFE tape.
o. Install tubing with extreme care to keep foreign matter out. Keep open ends of tubing plugged to keep out dust, dirt, and moisture.
p. Mark each tube on each end with a number-coded identification. Each tube shall have a unique number.
q. Test tubing as follows:

1) Test for leaks and obstructions. Disconnect each tubing run before test is run, and blow out trash, condensate, and other foreign material with compressed air.
2) After foreign matter is expelled and the line is free from obstructions, plug the far end of tubing run.
3) Connect a pressure source to the near end with a needle valve between air supply and tubing run. Only commercially pure dry compressed air or nitrogen as distributed in gas cylinders is acceptable for this test.

E. Control Panels:

1. Design control panels for grouping and protecting various electric, and/or electronic components.
2. NRTL listed in accordance with UL 50 or UL 50E.
3. NEMA 250, [**Type 1**] [**or**] [**Type 12**] <**Insert Type**> enclosure.
4. Construct enclosure of steel, not less than the following:

a. Enclosure Size Less Than 24 Inches: [**0.053 inch**] [**or**] [**0.067 inch**] thick.
b. Enclosure Size 24 Inches and Larger: [**0.067 inch**] [**or**] [**0.093 inch**] thick.

5. Support front panel using a non-removable piano hinge that runs entire height of cabinet.
6. Each panel shall not exceed height of air-handling unit casing and 72 inches high.

7. Secure front panel with a key locking mechanism. Common key the locks, and provide one pair of keys per panel.
8. Front panel with a window of size so all instrument displays are visible with door closed.
9. Mount panels on exterior wall of air-handling unit casing on primary access side of unit.
10. Paint control panel exterior with enamel at least 5 mils thick. Color of panel exterior and interior shall be white.
11. Include panel field power supply with a toggle-type switch located at entrance inside panel to disconnect power.
12. Include panel with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
13. Size control panel to provide at least 25 percent spare area on subpanel.
14. Arrange control panel so similar type equipment is grouped together, and a barrier is installed between electrical and electronic equipment.
15. Interior ambient temperature shall not rise above manufacturer's recommended maximum operating temperature for products installed within the panels. Provide filtered louvers and circulating fans, when necessary, to meet this criteria.
16. Panel shall serve as a central tie-in point for control devices such as remote sensors, transmitters, power supplies, and transformers.

    a. Factory install internal wiring in compliance with specified standards.
    b. Terminate wiring using an electric terminal strip with heavy-duty terminal blocks.
    c. Include spare terminals, equal to not less than [**10**] [**20**] <**Insert number**> percent of used terminals.
    d. Include spade lugs for stranded wire.
    e. Install a maximum of two wires on each side of a terminal.
    f. Label each end of cable, wire, and tubing within panel following an approved identification system.

17. Polyethylene tubing may be used within panel enclosure in place of copper.
18. Supply each control panel with a complete set of as-built schematics, tubing, and wiring diagrams that are bound in a three-ring protective binder and located within panel.
19. Mount instruments and other products within control panel on an internal panel(s) and provide with nameplates. Provide engraved, laminated phenolic nameplates (black letters on a white background). Nameplates shall have at least 1/4-inch-high lettering.
20. Route tubing, cable, and wiring located inside control panel within a raceway that has a continuous removable cover.

F. Pitot Tube Airflow Stations:

1. Fan Inlet Airflow Sensor (Piezometer Ring):

    a. <Double click here to find, evaluate, and insert list of manufacturers and products.>

    b. Source Limitations: Obtain sensors from single source from single manufacturer.

    c. Provide fans with airflow measurement integral to fan inlet cones for continuously measurement of air volume flow rate.

d. Fan inlet airflow sensor shall contain multiple pressure sensor points strategically placed along the circumference of the inlet cone and internally connected to an averaging ring manifold located behind the inlet cone.
e. Sensor points shall neither protrude beyond the surface of the inlet cone nor be adversely affected by particle contamination present in the airstream.
f. Sensor shall produce steady, non-pulsating signals to achieve accuracy within 5 percent of actual airflow.
g. Sensor shall be non-intrusive and not impact fan performance.
h. Product shall be a standard offering of fan manufacturer and include published literature with supporting test data to validate sensor performance.

G. Thermal Airflow Measurement Stations:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain stations from single source from single manufacturer.

3. Description: Airflow station shall consist of one or more sensor probes and a remotely mounted microprocessor-based transmitter.
4. Performance:

a. Capable of independently processing up to [**16**] <**Insert number**> independently wired sensor assemblies.
b. Airflow rate of each sensor assembly shall be equally weighted and averaged by transmitter prior to output.
c. Temperature of each sensor assembly shall be velocity weighted and averaged by transmitter prior to output unless temperature sensor has an accuracy of 0.1 deg F.
d. Listed and labeled by an NRTL as successfully tested as an assembly in accordance with UL 873 or UL 60730.
e. Components shall be interconnected by exposed NRTL-listed plenum-rated cable or non-plenum-rated cable placed in conduit.
f. Each flow station shall be factory calibrated at a minimum of [**six**] [**16**] <**Insert number**> airflow rates and [**two**] [**three**] <**Insert number**> temperatures to standards that are traceable to NIST.
g. Individual Sensor Airflow Accuracy: Within [**2**] [**3**] <**Insert number**> percent of reading over the entire operating airflow range.
h. Thermal Airflow Station Assembly Airflow Accuracy: Within [**2**] [**3**] [**5**] <**Insert number**> percent of reading over the entire operating airflow range.

1) Devices whose accuracy is combined accuracy of transmitter and sensor probes must demonstrate that total accuracy meets performance requirements throughout the measurement range.

i. Temperature Accuracy: Within 0.2 deg F over entire operating range of minus 20 to plus 140 deg F.
j. Sensor Ambient Operating Temperature Range: Minus 20 to plus 160 deg F.
k. Transmitter Ambient Operating Temperature Range: Minus 20 to plus 120 deg F.
l. Sensor and Transmitter Ambient Operating Humidity Range: Zero to 99 percent, noncondensing.
m. Instrument shall compensate for changes in air temperature and density throughout calibrated velocity range for seasonal extremes at Project location.

n. Pressure Drop: 0.05 inch wg at 2000 fpm across a 24-by-24-inch area.
o. Instruments mounted in throat or face of fan inlet cone shall not negatively influence fan performance by reducing flow more than [**1**] [**2**] <**Insert number**> percent of Project design flow or negatively impact fan-generated sound. Losses in performance shall be documented with submittal data, and adjustments to compensate for performance impact shall be made to fan to deliver Project design airflow indicated.

5. Sensor Assemblies:

a. Each sensor probe shall contain two individually wired, hermetically sealed [**bead-in-glass**]thermistors.
b. Mount thermistors in sensor using a marine-grade, waterproof material.
c. Thermistor leads shall be protected and not exposed to environment.
d. Each sensor assembly shall independently determine airflow rate and temperature at each measurement point.
e. Each sensor probe shall have an integral cable for connection to remotely mounted transmitter.
f. Sensor Probe Material: Gold anodized, extruded Alloy 6063 aluminum tube or Type 304 stainless steel.
g. Probe Assembly Mounting Brackets Material: Type 304 stainless steel.

6. Transmitter:

a. Integral digital display capable of simultaneously displaying total airflow and average temperature, individual airflow, and temperature readings of each independent sensor assembly.
b. Capable of field configuration and diagnostics using an onboard push-button interface and digital display.

1) Include an integral power switch to operate on 24-V ac (isolation not required) and include the following:

a) Integral protection from transients and power surges.
b) Circuitry to ensure reset after power disruption, transients, and brownouts.
c) Integral transformer to convert field power source to operating voltage required by instrument.

c. Remote Signal Interface:

1) Linear Analog Signals for Airflow[**and Temperature**]: Fuse protected and isolated, [**field selectable,**] [**0 to 10 V dc**] [**or**] [**4 to 20 mA**].
2) RS-485: BACnet-ARCNET, BACnet-MS/TP, and Modbus-RTU.
3) 10 Base-T Ethernet: BACnet Ethernet, BACnet-IP, Modbus-TCP, and TCP/IP.
4) LonWorks free topology.

H. Flow Transmitters for Pitot Tube Sensors:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain sensors from single source from single manufacturer.

3. Receives total and static pressure signals from a flow element, amplify, extract the square root, and scale the signal to produce a 4- to 20-mA dc output signal linear to airflow.
4. Housed in NEMA 250, Type 1 enclosure.
5. Assembly constructed so that shock, vibration, and pressures surges of up to 1 psigwill neither harm transmitter nor affect its accuracy.
6. Provide transmitter with an automatic zeroing circuit capable of automatically readjusting transmitter zero at predetermined time intervals. Automatic zeroing circuit shall re-zero transmitter to within 0.1 percent of true zero.
7. Performance:

   a. Range: At least 20 percent below minimum airflow and 20 percent greater than design airflow.
   b. Calibrated Span: Field adjustable, minus 40 percent of the range.
   c. Accuracy: Within 0.10 percent of natural span.
   d. Repeatability: Within 0.15 percent of calibrated span.
   e. Linearity: Within 0.2 percent of calibrated span.
   f. Hysteresis and Deadband (Combined): Less than 0.2 percent of calibrated span.

8. Equip transmitter with an integral digital LED or LCD for continuous indication of airflow.
9. Install in control panel.

I. Humidity Sensors and Transmitters with Digital Display:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain sensors and transmitters from single source from single manufacturer.

3. Performance:

   a. Accuracy including non-linearity, hysteresis, and repeatability: Within 2 percent from zero to 90 percent relative humidity and within 2.5 percent from 90 to 100 percent relative humidity when operating between 60 to 77 deg F.
   b. Relative Humidity Range: Zero to 100 percent.
   c. Factory calibrated and NIST traceable with certificate included.

4. Construction:

   a. Provide housing with remote sensor probe for ducted applications.

      1) Duct Sensor Body: 300 series stainless steel or chrome-plated aluminum, at least 2 inches long for duct-mounted applications.
      2) Provide sensor with cable for field installation in conduit.
      3) For duct-mounted applications, thread the sensor assembly for connection to a threaded mounting flange.

   b. Provide general-purpose humidity sensor unless application requires special requirements. Provide sensor with sintered stainless steel filter.

c. Housing shall be ABS/PC plastic or powder-coated aluminum.
d. Housing Classification: NEMA 250, Type 4 or Type 4X.
e. Provide housing with wall-mounting plate.

5. Output Signal: Two-wire, 4- to 20-mA output signal with a drive capacity of at least 500 ohms at 24 V dc.
6. Provide unit with a digital display of relative humidity in percent.

J. Air Pressure Sensors:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain sensors from single source from single manufacturer.

1. Insertion length shall be at [**4 inches**] [**6 inches**] [**8 inches**] [**12 inches**].
2. Sensor with four radial holes of 0.04-inch diameter.
3. [**Brass**] [**or**] [**stainless steel**] construction.
4. Sensor with threaded end support, sealing washers, and nuts.
5. Connection: NPS 1/4 compression fitting.

K. Air-Pressure Differential Indicating Transmitter, Switch, and Controller:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain from single source from single manufacturer.

3. Description:

a. Three-in-one instrument, including digital display, control relay switches, and a transmitter with a current output.
b. Field configurable for pressure, velocity, and volumetric flow applications through user interface.
c. Select instrument range based on application. Range shall be approximately 2 times set point.

4. Performance:

a. Accuracy Including Hysteresis and Repeatability:

1) Within 1 percent for ranges less than 5 inches wg.
2) Within 0.5 percent at 77 deg F for other ranges.

b. Stability: Within 1 percent per year.
c. Response Time: 250 ms.
d. Overpressure: 5 psig for instrument ranges less than 50 inches wg and 9 psig for 100-inch wg range.
e. Temperature Limits: 32 to 140 deg F.
f. Thermal Effects: 0.020 percent per deg F.
g. Warm-up Period: One hour.

5. Controller Programming through Menu Keys to Access Five Menus:

a. Security level.
b. Pressure, velocity, or flow application.
c. Engineering units.
d. K-factor for use with flow application.
e. Set-point control only; set-point and alarm operation; and alarm operation as high, low, or high/low with manual or automatic reset and delay.
f. View high and low readings.
g. Digital dampening for smoothing erratic applications.
h. Scaling of analog output to fit range and field calibration.

6. Display:

a. Digital, four-digit display with backlight, with 0.4-inch-high, alphanumeric characters.
b. Four indicators; two for set point and two for alarm status.

7. Operator Interface:

a. Set-point adjustment through keypad on face of instrument.
b. Zero and span adjustments accessible through menu.
c. Programming through keypad.

8. Analog Output Signal:

a. Two-wire, 4- to 20-mA dc current source.
b. Signal capable of operating into a 900-ohm load.

9. Digital Output Signal:

a. Two SPDT relays.
b. Each rated for 1 A at 30 V ac or dc.

10. Construction:

a. Die cast-aluminum casing and bezel.
b. Threaded, NPS 1/8 connections on side and back.
c. Vertical plane mounting.
d. NEMA 250, Type 1.
e. Nominal 4-inch-diameter face.
f. Mounting Bracket: Appropriate for installation.

L. Carbon Dioxide Sensors/Transmitters:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain sensors/transmitters from single source from single manufacturer.

3. Description:

a. NDIR technology or equivalent technology providing long-term stability and reliability.
b. Two-wire, 4- to 20-mA output signal; linearized to carbon dioxide concentration in ppm.

4. Construction:

a. House electronics in an ABS plastic enclosure. Provide equivalent of NEMA 250, Type 4.
b. Equip with digital display for continuous indication of carbon dioxide concentration.

5. Performance:

a. Measurement Range: 0 to 2000 ppm.
b. Accuracy: Within 2 percent of reading, plus or minus 30 ppm.
c. Repeatability: Within 1 percent of full scale.
d. Temperature Dependence: Within 0.05 percent of full scale over an operating range of 25 to 110 deg F.
e. Long-Term Stability: Within 5 percent of full scale after more than five years.
f. Response Time: Within 60 seconds.
g. Warm-up Time: Within five minutes.

6. Provide calibration kit. Turn over to Owner at start of warranty period.

M. Air Temperature Sensors:

1. Platinum Resistance Temperature Detector (RTD): Common Requirements:

a. 100 or 1000 ohms at 0 deg C and a temperature coefficient of 0.00385 ohms/ohm/deg C.
b. Two-wire PTFE-insulated 22-gauge stranded copper leads.
c. Performance Characteristics:

1) Range: Minus 50 to plus 275 deg F.
2) Interchangeable Accuracy: At 32 deg F within 0.5 deg F.
3) Repeatability: Within 0.5 deg F.
4) Self-Heating: Negligible.

d. Transmitter Requirements:

1) Transmitter required for each 100-ohm RTD.
2) Transmitter optional for 1000-ohm RTD, contingent on compliance with end-to-end control accuracy.

2. Platinum RTD, Averaging Sensor:

a. <Double click here to find, evaluate, and insert list of manufacturers and products.>

b. Source Limitations: Obtain sensors from single source from single manufacturer.

c. [**100**] [**or**] [**1000**] ohms.
d. Temperature Range: Minus 50 to plus 275 deg F
e. Multiple sensors to provide average temperature across entire length of sensor.
f. Rigid probe of aluminum, brass, copper, or stainless steel sheath.
g. Flexible probe of aluminum, brass, copper, or stainless steel sheath and formable to a 4-inch radius.
h. Length: As required by application to cover entire cross section of air tunnel.
i. Enclosure: Junction box with removable cover; NEMA 250, Type 4.
j. Gasket for attachment to duct or equipment to seal penetration airtight.
k. Conduit Connection: 1/2-inch trade size.

N. Air Temperature Switches:

1. Thermostat and Switch for Low Temperature Control:

a. <Double click here to find, evaluate, and insert list of manufacturers and products.>

b. Source Limitations: Obtain switches from single source from single manufacturer.
c. General:

1) Two-position control.
2) Field-adjustable set point.
3) Manual reset.
4) NRTL listed.

d. Performance:

1) Operating Temperature Range: 15 to 55 deg F.
2) Temperature Differential: 5 deg F, non-adjustable and additive.
3) Enclosure Ambient Temperature: Minus 20 to plus 140 deg F.
4) Sensing Element Maximum Temperature: 250 deg F.
5) Voltage: 120 V ac.
6) Current: 16 full-load A.
7) Switch Type: Two SPDT snap switches operate on coldest 12-inchsection along element length.

e. Construction:

1) Vapor-Filled Sensing Element: Nominal 20 feet long.
2) Dual Temperature Scale: Fahrenheit and Celsius visible on face.
3) Set-Point Adjustment: Screw.
4) Enclosure: Painted metal, NEMA 250, Type 1.
5) Electrical Connections: Screw terminals.
6) Conduit Connection: 1/2-inch trade size.

O. Air Temperature RTD Transmitters:

1. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2. Source Limitations: Obtain transmitters from single source from single manufacturer.

3. House electronics in NEMA 250 Type 1 enclosure. Mount transmitter in control panel.
4. Conduit Connection: 1/2-inch
5. Functional Characteristics:

    a. Input:

        1) 100-ohm platinum RTD temperature coefficient of 0.00385 ohms/ohms/deg C; two-wire sensors.
        2) 1000-ohm platinum RTD temperature coefficient of 0.00385 ohms/ohms/deg C; two-wire sensors.

    b. Span (Adjustable):

        1) Exhaust Air: 50 to 100 deg F.
        2) Mixed Air: Minus 40 to plus 140 deg F.
        3) Outdoor: Minus 40 to plus 140 deg F.
        4) Supply Air, Cooling, and Heating: 40 to 120 deg F.
        5) Return Air: 50 to 100 deg F.

    c. Output: 4- to 20-mA dc linear with temperature; RFI insensitive; minimum drive load of 600 ohms at 24 V dc.
    d. Zero and span field adjustments plus or minus 5 percent of span. Minimum span 50 deg F.
    e. Match sensor with temperature transmitter and factory calibrate together.

6. Performance Characteristics:

    a. Calibration Accuracy: Within 0.1 percent of span.
    b. Stability: Within 0.2 percent of span for at least 6 months.
    c. Combined Accuracy: Within 0.5 percent.

7. Provide each transmitter with a digital display.

P. Control Transformers:

1. Size each transformer for the total connected load, plus an additional 25 percent of the connected load.
2. Each transformer shall be at least 100 VA.
3. Provide transformer with both primary and secondary fuses.

Q. 25-V dc Power Supply:

1. Plug-in style suitable for mating with a standard eight-pin octal socket.
2. Enclose circuitry within a housing.
3. Include line and load regulation to ensure a stable output. To protect both power supply and load, include power supply with an automatic current limiting circuit.
4. Performance:

    a. Output voltage nominally 25 V dc within 5 percent.
    b. Output current up to 100 mA.
    c. Input voltage nominally 120 V ac, 60 Hz.

d. Load regulation within 0.5 percent from 0- to 100-mA load.
e. Line regulation within 0.5 percent at a 100-mA load for a 10 percent line change.
f. Stability within 0.1 percent of rated volts for 24 hours after a 20-minute warmup.

R. Instrument Identification:

1. Engraved tag bearing instrument identification.

a. Each tag identifying an instrument shall have a unique identification that does not match identification of a similar device.
b. Tag field instruments identified by equipment being controlled or monitored, followed by point identification used on I/O schematics.
c. Example: DDC-AHU-01.01; PDIT1.

2. Letter size shall be minimum 1/4 inch high.
3. Letter type shall be sans serif gothic bold style.
4. Lettering and background color scheme shall be white letters on black background.
5. Tag shall be engraved phenolic constructed of three layers of pressure rigid laminate. Top and bottom layers are color-coded, contrasting white center is exposed by engraving through outer layer. Engrave both sides. Material shall be stain proof, heat resistant, non-conductive, or non-corrosive.
6. Tag shall be fastened to equipment/instrument with drive pins or attached with a stainless steel chain.
7. Instruments furnished with identification tags provided by original manufacturer do not require an additional tag.

S. Checkout Procedures:

1. Check instruments for proper location and accessibility.
2. Check instruments for proper installation for direction of flow, elevation, orientation, and other applicable considerations.
3. Damper Check-out: Verify that proper blade alignment, either parallel or opposed, has been provided.

T. Calibration and Adjustment:

1. Calibrate every instrument.
2. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
3. Equipment and procedures used for calibration shall meet requirements of instrument manufacturer's written instructions. Test equipment used in calibration of instruments shall have an accuracy at least double that of instrument being calibrated.
4. Calibrate each instrument in accordance with the accuracy outlined in instruction manual supplied for instrument by manufacturer.
5. Control System Inputs and Outputs:

a. Check analog inputs using a precision voltage or current source at zero, 50, and 100 percent of span.
b. Check analog outputs using a milliampere meter at zero, 50, and 100 percent output.
c. Check digital inputs using a jumper wire.

d. Check digital outputs using an ohmmeter to test for contact making or breaking.
e. Check resistance temperature inputs at zero, 50, and 100 percent of span using a precision-resistant source.

6. Flow: Set differential pressure flow transmitters for zero and 100 percent values with three-point calibration accomplished at 100, 50, and 90 percent of span.
7. Gas: Calibrate gas transmitters at zero, 50, and 100 percent of span.
8. Humidity: Calibrate relative humidity transmitters at zero, 50, and 100 percent of span.
9. Pressure: Calibrate pressure transmitters at zero, 50, and 100 percent of span.
10. Temperature: Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.
11. Dampers: Stroke and adjust control dampers following the recommended procedure from manufacturer, such that damper is 100 percent open and closed.
12. Replace out-of-tolerance instruments failing the test.
13. Provide diagnostic and test instruments for calibration and adjustment.

2.42 SMOKE DETECTORS

A. System, Duct Smoke Detectors: For connection to conventional fire-alarm system. Coordinate requirements with Section 284621.13 "Conventional Fire-Alarm System."

1. Operating at 24 V dc, nominal.
2. Detectors shall be [**four**] [**two**]-wire type.
3. Base Mounting: Detector and associated electronic components shall be mounted in a twist-lock module that connects to a fixed base. Provide terminals in the fixed base for connection to building wiring.
4. Self-Restoring: Detectors do not require resetting or readjustment after actuation to restore them to normal operation.
5. Integral Visual-Indicating Light: LED type, indicating detector has operated[**and power-on status**].
6. Provide multiple levels of detection sensitivity for each sensor[**, with alarm-verification feature**].
7. Duct Smoke Detectors: Photoelectric type complying with UL 268A.

a. Remote indication[**and test**] station.[**Operating key switch initiates an alarm test.**]
b. Enclosure: NEMA 250, Type 4X; NRTL listed for use with the supplied detector for smoke detection in HVAC systems.
c. Sampling Tubes: Design and dimensions as recommended by manufacturer for specific size, air velocity, and installation conditions where applied.
d. Relay Fan Shutdown: Rated to interrupt fan motor-control circuit.

B. Nonsystem, Single-Station Duct Smoke Detectors:

1. Nonsystem smoke detectors shall be listed as compatible with fire-alarm equipment installed or shall have a contact closure interface listed for the connected load.
2. Nonsystem smoke detectors shall comply with the monitoring for integrity requirements in NFPA 72.
3. Comply with UL 268A; operating at 120 V ac.

4. Base Mounting: Detector and associated electronic components shall be mounted in a twist-lock module that connects to a fixed base. The fixed base shall be designed for mounting directly to mounting brackets air-handling unit. Provide terminals in the fixed base for connection to building wiring.

    a. Enclosure: NEMA 250, Type 4X; listed for use with the supplied detector.

5. Sampling Tubes: Design and dimensions as recommended by manufacturer for specific size, air velocity, and installation conditions where applied.
6. Relay Fan Shutdown: Rated to interrupt fan motor-control circuit.

C. Air-Handling Unit Factory Assembly:

1. Furnish and install smoke detectors inside air-handling units to comply with governing building codes.
2. Install smoke detectors in accordance with smoke detector manufacturer's written installation instructions.

    a. Sampling tubes shall extend the full width of airstream.
    b. Sampling tubes greater than 36 inches long shall be supported on both ends.

3. Install smoke detectors within air-handling units in a location that is easily accessible for inspection, repair, and replacement of smoke detector, and in a location that does not hinder access to other internal components.

D. Air-Handling Unit Factory Testing: Functionally test smoke detectors to ensure proper operation in accordance with smoke detector manufacturer's written instructions.

E. Air-Handling Unit Factory Installation of Addressable Smoke Detectors Furnished by Building Fire-Alarm System Supplier:

1. Where addressable duct smoke detectors are indicated to be installed within air-handling unit casing, air-handling unit manufacturer shall install duct smoke detector components supplied by building fire-alarm system supplier.
2. Mount duct smoke detector sampling housing on exterior of air-handling unit casing. Locate on accessible side and coordinate with installers before installation.
3. Seal air-handling unit casing penetrations.
4. Install duct smoke detector components in accordance with written instructions furnished by supplier.

    a. Sampling tubes shall extend the full width of airstream.
    b. Sampling tubes greater than 36 inches long shall be supported on both ends.

5. Photograph installation and transmit photos to fire-alarm system Installer before air-handling unit shipment to ensure proper installation. Fire-alarm system Installer shall review photos and provide written acceptance of installation to air-handling unit manufacturer before air-handling unit shipment.

    a. Document date of photos and approval for record purposes.
    b. Make corrective measures required by fire-alarm system Installer as required for acceptance.

6. Coordinate work schedule of air-handling unit manufacturer and fire-alarm system supplier to meet requirements of Project schedule.
7. See [**Section 284621.11 "Addressable Fire-Alarm Systems"**] <**Insert Section**> for additional requirements.

2.43 CATWALKS, HANDRAILS, AND LADDERS

A. General:

1. Provide elevated air-handling units and top levels of multilevel stacked units with catwalks, handrails, and ladders to provide service access.
2. Factory-fabricate catwalks, handrails, and ladders to ensure proper alignment and attachment.
3. Catwalks, handrails, and ladders may be disassembled and shipped separate from the air-handling unit for field installation.
4. Design and fabricate catwalk to be completely self-supported from air-handling unit frame without need for any type of field-installed supports.
5. Comply with OSHA requirements where requirements are more stringent than requirements indicated.
6. Install catwalk, handrails, and ladders level and plumb.

B. Catwalks:

1. Extend catwalks to service elevated portions of air-handling unit.
2. Catwalk width shall be of sufficient size to properly access and service equipment and maintain code-required clearances to electrical devices. Width shall be at least [**60 inches**] <**Insert dimension**> clear between the exterior casing and handrail.
3. Cantilever catwalk base frame from the air-handling unit base frame. Removable catwalks shall bolted to the air-handling unit base frame at multiple points to ensure a rigid and firm attachment.
4. Catwalk base frame material and finish shall match air-handling unit frame.
5. Catwalk floor material shall match air-handling unit floor material.
6. Catwalk walking surface elevation shall match floor surface inside air-handling unit.

C. Handrails:

1. Provide catwalk with handrail, kneerail, toeboard, and vertical supports along entire length of catwalk. Comply with 29 CFR 1910.23.
2. Handrail shall be a minimum of [**42 inches**] <**Insert dimension**> high and comply with OSHA requirements. Vertical supports shall be spaced not more than [**96 inches**] <**Insert dimension**> o.c.
3. Construct handrail, kneerail, and vertical supports from not less than nominal [**1-1/2-inch-**] <**Insert dimension**> diameter tube.
4. Handrail shall be capable of withstanding a live load force of not less than [**100 lb./ft.**] and a [**200-lb**] <**Insert value**> concentrated force in any direction.
5. Provide lift-out sections of handrail to facilitate removal of air-handling unit internal components from the top-level to grade.
6. Provide self-closing gate at ends of catwalk accessible by ladders to provide fall protection.

7. Construct handrails, kneerails, toeboards, and vertical supports of [**aluminum**] [**fiberglass**] [**galvanized-steel**] [**or**] [**stainless steel**] materials.

    a. Finish: Hot-dip galvanize assemblies constructed of steel after fabrication.

D. Ladders with Safety Cages:

1. Provide a permanently attached ladder at [**one**] [**each**] end of catwalk.
2. Ladder shall rise from building structural floor to the top of handrail.
3. Provide for construction tolerance and adjustable means to fasten the ladder at its base to the building structural floor.
4. Fabricate ladders with dimensions, spacing, details, and anchorages as required.
5. Comply with requirements of ALI A14.3 and 29 CFR 1910.27.
6. Support each ladder at top and bottom. Use welded or bolted brackets, designed for adequate support and anchorage, and to hold ladder [**7 inches**] <**Insert dimension**> clear from catwalk walking surface.
7. Extend rails at least [**42 inches**] <**Insert dimension**> above top rung, and return rails with secure handholds fastened to handrail.
8. Construct ladders of [**aluminum**] [**fiberglass**] [**galvanized-steel**] [**or**] [**stainless steel**] materials.

    a. Finish: Hot-dip galvanize ladders, brackets, and fasteners constructed of steel after fabrication.

9. Provide non-slip surface on top of each rung, either by coating rung with aluminum-oxide granules set in epoxy-resin adhesive or by using a type of manufactured rung that has a non-slip top surface.

2.44 HARDWARE

A. Screws:

1. For Galvanized-Steel Materials: Self-tapping, hex-head, [**zinc-plate steel**] [**or**] [**300 series stainless steel**] screws with a neoprene gasket encapsulated by a [**zinc-plate steel**] [**or**] [**300 series stainless steel**] washer.
2. For Aluminum and Stainless Steel Materials: Self-tapping, hex-head, 300 series stainless steel screws with a neoprene gasket encapsulated by a 300 series stainless steel washer.
3. Provide protective covers on exposed screws to prevent personnel injury.

B. Bolts, Nuts, and Washers:

1. For Joining Galvanized and Painted Carbon-Steel Materials: Hex-head, high-strength, [**galvanized steel**] [**or**] [**300 series stainless steel**].
2. For Joining Aluminum and Stainless Steel Materials: Hex-head, high-strength, 300 series stainless steel.
3. Use washers and lock washers at each bolted connection.
4. Select bolt size and spacing sufficient for load and application.

2.45 WELDING

A. Welding Filler Metals: Comply with AWS welding codes for welding materials appropriate for thickness and chemical analysis of material being welded.

1. Use welding materials with corrosion properties equal to material being welded.

B. Use welders that are certified to weld at least [**twice**]the thickness of the material to be welded. Certification shall be within [**three**] [**six**] <**Insert number**> months of work being performed.

C. Welds shall be continuous, full-penetration welds unless otherwise indicated. Intermittent welds, stitch welds, and tack welds are permitted only in specific applications indicated.

D. Use welders and welding procedures complying with the following:

1. Piping Systems: Section IX of the ASME Boiler and Pressure Vessel Code and Section V of ASME B31.1.
2. Structural Aluminum: AWS D1.2/D1.2M.
3. Structural Carbon Steel: AWS D1.1/D1.1M.
4. Structural Stainless Steel: AWS D1.6/D1.6M.
5. Sheetmetal: AWS D9.1/D9.1M.

2.46 PAINTING

A. General:

1. Painted OEM components do not require additional coating other than touchup to damaged areas. Match the touchup coating to surrounding undamaged surfaces.
2. Finish miscellaneous surfaces to match continuous surfaces.
3. Protect mill galvanized surfaces that are exposed to view, such as raw steel cuts and damage by welding, with multiple coats of matching galvanized paint.
4. Protect mill galvanized surfaces that are concealed, such as raw steel cuts and damage by welding, with multiple coats of zinc-rich paint or matching galvanized paint.
5. Touch up or entirely repaint surface finishes, damaged during shipment and installation, to the original condition, using original materials and methods.

B. Preparation:

1. Submit proposed manufacturer's written preparation and application instructions for information.
2. If paint manufacturer's recommended preparation requirements differ from those indicated, use the more stringent requirements.
3. Structural carbon steel to be painted shall be deburred, ground smooth, cleaned, and blasted in accordance with [**SSPC-SP 6/NACE No. 3**] [**or**] [**SSPC-SP 10/NACE No. 5**].
4. Before applying a primer and a finish coat, remove oil and grease from surfaces to be coated using clean rags soaked in thinner in accordance with SSPC-SP 1.
5. Treat surfaces to be painted to ensure that paint adheres.

C. Primer:

1. Rust-inhibiting type, with a minimum dry film thickness of [**1**] [**2**] <**Insert value**> mil(s) per coat.

2. Apply at least [**two**] <**Insert number**> coats of primer to unfinished carbon-steel surfaces and at least one coat of primer to other surfaces.
3. Use primer that is compatible with substrate and finish coat.

D. Finish Coat:

1. Finish coat painting system shall be [**alkyd-enamel**] [**epoxy**] [**polyurethane**] <**Insert coating**>.
2. Use dry film thickness recommended by paint manufacturer for each coat. Total dry film thickness of all finish coats not less than [**3**] [**5**] <**Insert value**> mils.
3. Painted Surfaces Minimum Properties:

a. Salt Spray ASTM B117: 5 percent salt solution fog at 95 deg F for [**500**] [**1000**] [**2000**] hours with no deterioration.
b. Adhesion ASTM D3359: When the coating is cut into 0.0625-inch squares and 3M No. 600 tape is suddenly removed, there is no loss of adhesion.
c. Acid Resistance ASTM D3260: 15-minute exposure to 10 percent hydrochloric acid at room temperature with no effect.
d. Alkali Resistance ASTM D1647: 15-minute exposure to 10 percent sodium hydroxide at room temperature with no effect.
e. Humidity Resistance ASTM D2247: 850-hour exposure to 100 deg F and at least 95 percent relative humidity with no effect.
f. Pencil Hardness ASTM D3363: A hardness of 1H.

4. Finish coat color shall be selected by Architect and not be limited to manufacturer's standard offering.

a. Submit a written request for color selection and indicate in the request the date color selection must be returned without impacting schedule.

E. Application: Paint the following surfaces with primer and finish coat indicated:

1. Unfinished carbon-steel surfaces.
2. Exposed mill galvanized-steel surfaces of air-handling unit casing exterior.
3. Exposed aluminum surfaces of air-handling unit casing exterior.
4. Exposed stainless steel surfaces of air-handling unit casing exterior.

2.47 CLEANLINESS REQUIREMENTS

A. General:

1. Provide equipment that has been manufactured, shipped, stored, and installed maintaining highest degree of cleanliness possible.
2. Owner Cleanliness Inspection: Air-handling unit(s) cleanliness is subject to Owner cleanliness inspection [**and must pass a white glove test**]before packaging for shipment.
3. <**Insert requirements**>.

B. During Manufacturing:

1. Clean materials to be free of mill grease, oxidation, dirt, dust, and other impurities before manufacturing and assembly.
2. Protect casing materials from contamination during manufacturing and assembly.
3. Use sealing materials that do not outgas.
4. Provide OEM components and equipment from their respective manufacturers free of grease, oxidation, and dirt. Store OEM components and equipment indoors. Cover and protect OEM components and equipment to maintain cleanliness. Follow OEM instructions for equipment storage.

C. After Manufacturing:

1. Before shipment, after unit is completely assembled, clean unit inside and out.

   a. Vacuum entire inside to remove dirt, dust, and debris using HEPA-filtered vacuum equipment.
   b. Purge hard to reach surfaces with dry, oil-free, compressed or bottled nitrogen.
   c. Wipe down all surfaces, inside and out, with a residue-free cleaning agent.

2. Protect unit to maintain cleanliness.

D. Shipping:

1. Protect interior and exterior of air-handling unit from exposure to weather dirt, dust, and debris during shipment and rigging.
2. Cover openings with puncture-resistant durable coverings to ensure that cleanliness is maintained inside unit while providing an air- and watertight seal.

E. On-Site Storage:

1. If air-handling unit is to be stored before installation, Installer shall work closely with air-handling unit manufacturer for air-handling unit manufacturer to provide adequate protection at the factory to ensure that cleanliness for both unit interior and unit exterior is maintained. This protection shall remain in place until unit startup is performed.
2. For extended periods of storage, provide a means to rotate fan and motor assemblies on a periodic basis (as recommended by manufacturer) without compromising unit cleanliness.

2.48 ACCESSORIES

A. Tool Kit:

1. Manufacturer shall assemble a tool kit specially designed for use in servicing air-handling units furnished.
2. Include only special tools required to service air-handling unit components not readily available for purchase by Owner service personnel in performing routine maintenance.
3. Place tools in a lockable case with hinged cover.
4. Mark case cover with large and permanent text to indicate special purpose of tool kit, such as "Air-Handling Unit Tool Kit." Text size shall be at least [**1 inch**] <**Insert dimension**> high.

5. Provide a list of each tool furnished and permanently attach the list to underside of case cover. Text size shall be at least [**1 inch**] <**Insert dimension**> high.

2.49 SOURCE QUALITY CONTROL

A. AHRI Compliance:

1. AHRI 260 (I-P): Air-handling unit sound ratings shall be in accordance with AHRI 260 (I-P), "Sound Rating of Ducted Air Moving and Conditioning Equipment."
2. AHRI 261 (SI): Air-handling unit sound ratings shall be in accordance with AHRI 261 (SI), "Sound Rating of Ducted Air Moving and Conditioning Equipment."
3. AHRI 410: Air-handling unit coils shall be rated in accordance with AHRI 410 and shall be listed by AHRI[**and labeled in accordance with AHRI**].
4. AHRI 1060 (I-P) Certification: Air-handling units that include [**energy wheels**] [**fixed plate heat exchangers**] [**and**] [**heat pipe heat exchangers**] shall be rated in accordance with AHRI 1060 (I-P) and shall be listed by AHRI[**and labeled in accordance with AHRI**].
5. AHRI 1061 (SI) Certification: Air-handling units that include [**energy wheels**] [**fixed plate heat exchangers**] [**and**] [**heat pipe heat exchangers**] shall be rated in accordance with AHRI 1061 (SI) and shall be listed by AHRI[**and labeled in accordance with AHRI**].

B. AMCA Compliance:

1. AMCA 201: Air-handling unit manufacturer shall evaluate fan's performance within the air-handling unit in accordance with AMCA 201, "Fans and Systems" and account for conditions within the air-handling unit that could be detrimental to fan's performance by adjusting the fan performance indicated on Drawings.
2. AMCA 205 Certification: Air-handling unit fan's fan efficiency grade (FEG) shall be rated in accordance with AMCA 205, "Energy Efficiency Classifications for Fans"[**and shall bear the AMCA-certified FEG seal**].
3. AMCA 210 Certification: Air-handling unit fan's air performance shall be rated in accordance with AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating"[**and shall bear the AMCA-certified air ratings seal**].
4. AMCA 300: Air-handling unit fan's sound performance shall be rated in accordance with AMCA 300, "Reverberant Room Method for Sound Testing of Fans."
5. AMCA 301 Certification: Air-handling unit fan's sound performance shall be rated in accordance with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data"[**and shall bear the AMCA-certified sound ratings seal**].
6. AMCA 500-D: Air-handling unit damper's performance shall be rated in accordance with AMCA 500-D, "Laboratory Methods of Testing Dampers for Rating"[**and shall bear the AMCA-certified air ratings seal**].

C. NFPA Compliance:

1. NFPA 70: Electrical components, devices, and accessories shall be listed and labeled by a qualified testing agency, and marked for intended location and application.
2. NFPA 90A: Design, fabrication, and installation of air-handling units and components shall comply with NFPA 90A.

D. UL Compliance:

1. UL 1598 Certification: Air-handling unit UVGI shall be NRTL listed and labeled in accordance with UL 1598, "Luminaires."
2. UL 1995 Certification: Where indicated, air-handling unit components shall be NRTL listed and labeled in accordance with UL 1995, "Standard for Safety Heating and Cooling Equipment."

2.50 SOURCE QUALITY CONTROL - INDEPENDENT LABORATORY TESTING

A. General:

1. Project-specific testing by an independent laboratory is not required if air-handling unit manufacturer has written independent laboratory test results of past tests performed on same casing construction proposed for use on this Project.
2. If Project-specific testing is required, testing shall be performed in ample time to include test reports with submittals and before manufacturing of air-handling units. Include sufficient lead time for unit delivery, installation, and testing required by construction schedule.

B. Casing Structural Deflection Test:

1. Include service of an independent testing laboratory to verify casing structural deflection requirements indicated.

   a. In lieu of independent laboratory testing, manufacturer may perform factory deflection testing of proposed construction to prove compliance if witnessed by [**Architect**] [**and**] [**Owner**]. Manufacturer shall bear cost of labor and travel expenses to witness testing.

2. Test casing construction to performance criteria indicated.
3. Test casing construction proposed for use on Project. Include, at a minimum, particulars such as metal materials and thickness, internal support and reinforcing, and insulation material and thickness.
4. Test largest full-size casing panel proposed for use on Project.
5. Test proposed construction of walls, floor, and roof. Include a separate test for each unique casing construction proposed.
6. Submit test reports for each test to show compliance with performance indicated.

C. Casing Airborne Sound Transmission Test:

1. Include services of an independent testing laboratory to test proposed casing construction for sound transmission. Include a separate test for each unique casing construction proposed.
2. Conduct tests in accordance with ASTM E90.
3. Determine sound transmission class by using ASTM E413.
4. Test proposed construction of walls and roof.
5. Test proposed construction of floor assembly only if air-handling unit is not installed on a concrete housekeeping pad or building structural floor.
6. Submit test reports for each test to show compliance with performance indicated.

D. Casing Sound Absorption Test:

1. Include services of an independent testing laboratory to verify casing sound absorption coefficients for perforated casing panels. Provide a separate test for each unique casing construction proposed.
2. Conduct tests in accordance with ASTM C423 and ASTM E795.
3. Test proposed construction of walls and roof.
4. Submit test reports to show compliance with performance indicated.

2.51 SOURCE QUALITY CONTROL - AIR-HANDLING UNIT FACTORY TESTS

A. Witness of Testing: Allow [**Architect**] [**Commissioning Agent**] [**Construction Manager**] [**and**] [**Owner**] <**Insert entity**> access to place where air-handling units are being tested for witness testing.

1. Submit written notification at least [**30**] [**20**] <**Insert number**> days in advance of testing.
2. Schedule testing at mutually agreeable dates and times.

B. Witness Testing Travel Expenses:

1. Include in bid, the cost of travel expenses to witness factory testing. Total cost for travel expenses shall be clearly indicated separately in bid.
2. Expenses shall include roundtrip [**coach**] [**or**] [**first**] class airfare, out-of-town hotel accommodations, out-of-town meals (breakfast, lunch, and dinner), out-of-town ground transportation and parking, and all associated taxes and fees.
3. Exclude other incidental expenses not indicated.
4. Include travel expenses for [**one**] [**two**] <**Insert number**> representative(s) with origin of <**Insert city and state**>.

C. Casing Leakage Test:

1. Perform a leak test for [**each assembled air-handling unit**] [**each assembled air-handling unit of unique size and arrangement**] <**Insert requirement**>.
2. Follow testing procedures in accordance with ASHRAE 111.
3. Perform leak test before shipping first air-handling unit[**of unique size and arrangement**].
4. Test results shall indicate that units comply with leakage requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
5. Prepare test reports in accordance with ASHRAE 111.
6. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

D. Casing Structural Deflection Test:

1. Perform a structural deflection test for [**each assembled air-handling unit] [each assembled air-handling unit of unique size and arrangement**] [**only one air-handling unit with the worst-case condition**] <**Insert requirement**>.
2. Pressurize and load air-handling units to the performance criteria indicated for structural deflection. Test air-handling unit [**floors**] [**walls and roofs**].
3. Test results shall indicate that units comply with deflection requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
4. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

E. Functional Run Test:

1. Run test each unit before shipment.
2. Test and balance fans to comply with vibration requirements indicated.
3. Energize each electrical device to ensure that it is operational.

    a. Take meter readings for volts, amperes, and kVAr on each phase leg of each motor.
    b. Take meter readings for volts, amperes, and kVAr on each single-phase power connection to field power.

4. Exercise each damper to ensure proper operation.
5. Exercise each access door to ensure proper fit.
6. Exercise each valve to ensure proper operation.
7. Submit a written report for each unit tested. Written report shall include, at a minimum, full name of each person witnessing test, detailed list of each unit component tested, condition observed, and corrective action required. Each line item shall have full name of the person doing the checkout and date and time the checkout was performed.

F. Fan Vibration Test:

1. Perform a fan vibration test for [**each assembled air-handling unit**] [**each assembled air-handling unit of unique size and performance**] <**Insert requirement**>.
2. Energize each fan within the air-handling unit after air-handling unit final assembly and perform a vibration analysis with fan operating at design speed[**and at all speeds throughout the range from design to minimum speed**].
3. Three vibration measurements shall be taken for each bearing in horizontal, vertical, and axial directions. Vibration measurements shall be recorded and consist of vibration amplitude verses frequency[**with filter-in**].
4. Fan bearing measurement points shall be marked or scribed on bearings for permanent record.
5. Test results shall indicate that units comply with vibration requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
6. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests

and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

G. Acoustical Performance Test:

1. Perform an acoustical performance test for [**each assembled air-handling unit**] [**each assembled air-handling unit of unique size and performance**] <**Insert requirement**>.
2. Air-handling unit acoustic performance shall be verified by factory test in accordance with AHRI 260 (I-P) and AHRI 261 (SI).
3. Air-handling unit supply-air discharge, return-air inlet, and casing radiated sound components shall be measured with air-handling unit operating at design conditions.
4. Testing Location: Perform testing in a location complying with AHRI 220, "Reverberation Room Qualification and Testing Procedures for Determining Sound Power of HVAC Equipment."

    a. Test location shall be broadband qualified in accordance with AHRI 220 Section 5.1 and discrete frequency qualified in accordance with Section 5.2.

5. Operating conditions used in acoustic testing shall be verified by test in accordance with AMCA 210[**in an AMCA-accredited facility**].
6. Test results shall indicate that units comply with acoustical requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
7. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

H. Airflow Capacity Performance Test:

1. Perform an airflow capacity performance test for [**each assembled air-handling unit**] [**each assembled air-handling unit of unique size and performance**] <**Insert requirement**>.
2. Operating conditions shall be verified by test in accordance with AMCA 210[**in an AMCA-accredited facility**].
3. Test results shall indicate that units comply with design airflow requirements indicated. Make changes to noncompliant air-handling units and retest until units comply with requirements.
4. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single air-handling unit, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

2.52 SOURCE QUALITY CONTROL - OEM COMPONENT FACTORY TESTS

A. Air Mixer Testing:

1. Owner-witnessed performance test to demonstrate compliance with performance requirements indicated.

B. Coil Testing:

1. Hydronic Coils: Factory tested with air while coil is completely submerged underwater to design pressure indicated, but not less than [**300-psig**] <**Insert pressure**> internal pressure.
2. Refrigerant Coils: Factory tested with air while coil is completely submerged underwater to design pressure indicated, but not less than [**300-psig**] <**Insert pressure**> internal pressure.
3. Steam Coils: Factory tested with air while coil is completely submerged underwater to design pressure indicated, but not less than to [**300-psig**] <**Insert pressure**> internal pressure.
4. Coils to display a tag with inspector's identification as proof of testing.

C. Fan Vibration Testing:

1. Perform a fan vibration test for [**each fan**] <**Insert requirement**>.
2. Energize each fan after final assembly and perform a vibration analysis with fan operating at design speed[**and at all speeds throughout the range from design to minimum speed**].
3. Three vibration measurements shall be taken for each bearing in horizontal, vertical, and axial directions. Vibration measurements shall be recorded and consist of vibration amplitude verses frequency[**with filter-in**].
4. Fan bearing measurement points shall be marked or scribed on bearings for permanent record.
5. Test results shall indicate that units comply with vibration requirements indicated. Make changes to noncompliant fans and retest until fans comply with requirements.
6. Submit test reports indicating test location, documentation of test equipment used, test procedures, test results, test date and time, and full names of personnel performing tests and witnesses. If multiple tests are required to achieve compliance for a single fan, report shall include test date and time, test results, and full names of personnel performing tests and witnesses of each test with a detailed description and photographs of interim corrective measures made before each retest.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine air-handling units before installation. Reject units with physical damage, and air-handling unit components that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for the following before installation of air-handling units:

1. Structural substrate mounting and anchorage to verify actual sizes, types, and locations.
2. Piping systems to verify actual sizes, types, and locations of connections.
3. Ductwork and plenums to verify actual sizes, types, and locations of connections.
4. Electrical services and controls to verify actual sizes, types, and locations of connections.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Equipment Mounting: Install air-handling units at locations indicated on Drawings. Unless, otherwise indicated on Drawings, install air-handling units on concrete equipment bases.

1. Units Mounted on Concrete Bases:

    a. Install air-handling units on cast-in-place concrete equipment bases. Coordinate sizes and locations of concrete bases with actual equipment provided. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
    b. Level air-handling unit bases using aluminum or stainless steel shims compatible with air-handling unit base material.
    c. Fill voids between air-handling unit bases and concrete bases using high-strength non-shrink grout.
    d. Continuously seal between concrete bases and perimeter of air-handling unit bases with nonhardening sealant.

2. Units Mounted to Structural-Steel Supports: Level unit air-handling bases using aluminum or stainless steel shims compatible with air-handling unit base material. Continuously seal between structural supports and air-handling unit bases with nonhardening sealant.
3. Units Mounted Directly to Finished Floors: Level air-handling unit bases using aluminum or stainless steel shims compatible with air-handling unit base material. Continuously seal between floor and perimeter of air-handling unit bases with nonhardening sealant.
4. Suspended Units: Suspend and laterally brace air-handling units from building structure by attaching to only air-handling unit bases at manufacturer-designated locations.
5. Comply with requirements for seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

B. Equipment Clearances and Access:

1. Arrange installation of air-handling units to provide access space around air-handling units for service and maintenance and for removal and replacement of internal components.
2. Provide clearance and access required by governing codes and NFPA 70.
3. At a minimum, comply with requirements indicated on Drawings and air-handling unit manufacturer's written instructions.

3.3 PROTECTION DURING CONSTRUCTION

A. Exterior Covers: Cover air-handling units during construction with sealed covers to protect air-handling unit casing and externally mounted components from physical damage, dirt, dust and debris, paint splatter, and any other construction materials.

1. Minor physical damage, as determined by Owner, shall be repaired by air-handling unit factory service personnel to factory-finished condition.
2. Replace air-handling units with damage that in any way compromises the performance indicated.

B. Internal Access: Keep access doors locked to maximum extent possible and restrict access to only authorized personnel.

1. Open access doors only during periods authorized work inside air-handling units is required.
2. Coordinate and monitor work inside air-handling units on a shift basis. Lock access doors once work is complete or at the end of each shift.
3. Immediately report unauthorized access and any observed damage to Owner.

3.4 DUCT CONNECTIONS

A. Connect ducts and plenums to air-handling unit connections. Comply with requirements in Section 233113 "Metal Ducts."

B. Connect ducts and plenums to air-handling unit connections with flexible connections. Comply with requirements in Section 233300 "Air Duct Accessories."

C. Provide duct transitions required to make field connections to air-handling units.

D. Arrange ducts and plenums to provide unobstructed access to inside of air-handling units.

3.5 PIPING CONNECTIONS

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to air-handling unit, provide unobstructed access to inside of air-handling units for service and maintenance.

C. Connect piping to air-handling units with flexible connectors.

D. Drain Pan Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping."

1. Make connections to air-handling unit connections with [**flanges or**]unions.
2. Extend [**dedicated**]drain piping from each air-handling unit connection to nearest equipment or floor drain and arrange piping to maintain clear service aisle paths free of potential tripping hazards.
3. Construct traps near air-handling unit connections to seal airflow from escaping within air-handling unit. Locate traps in a serviceable location that is away from access doors.
4. Install threaded cleanouts at changes in direction.

5. Secure drain piping to structure.

E. Air-Handling Unit Floor Drains: Do not require installation of permanent drain piping.

F. Air-Handling Unit Floor Drain Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping."

1. Make connections to air-handling unit connections with [**flanges or**]unions.
2. Extend [**dedicated**]drain piping from each air-handling unit connection to nearest equipment or floor drain and arrange piping to maintain clear service aisle paths free of potential tripping hazards.
3. Construct traps near air-handling unit connections to seal airflow from escaping within air-handling unit. Locate traps in a serviceable location that is away from access doors.
4. Install threaded cleanouts at changes in direction.
5. Secure drain piping to structure.

G. Chilled-[**and Hot-**]Water Coil Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."

1. Comply with requirements indicated on Drawings.
2. Make connections to coils with a [**flange**] [**or**] [**union**].
3. Connect to each coil inlet with shutoff valve, test plug, [**pressure gauge**] [**and**] [**thermometer**].
4. Connect to each coil outlet with balancing valve, test plug, [**pressure gauge**] [**thermometer**] [**flow meter**] [**and**] [**shutoff valve**].
5. Connect each coil drain connection with a drain valve, which is full size of drain connection.[**Connect drain pipe to drain valve with union, and extend drain pipe to terminate over floor drain.**]
6. Connect each coil vent connection with [**automatic**] [**or**] [**manual**] vent, which is full size of vent connection.

H. Steam and Condensate Coil Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Heating Piping Specialties." Install shutoff valve at steam supply connections, float and thermostatic trap assembly, and union or flange at each coil return connection.

I. Refrigerant Coil Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping." Install shutoff valve at each supply and return connection.

J. Steam Humidifier Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Heating Piping Specialties." Install gate valve and inlet strainer at supply connection of steam humidifiers and steam trap assemblies to condensate return connection.

3.6 ELECTRICAL CONNECTIONS

A. Install field power to each air-handling unit electrical power connection. Coordinate with air-handling unit manufacturer and installers.

B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

D. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

E. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.

1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least [**1/2 inch**] <**Insert dimension**> high.

3.7 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

C. Install nameplate for each control connection, indicating field control panel designation and I/O control designation feeding connection.

3.8 STARTUP SERVICE

A. Engage an air-handling unit factory[**-authorized**] service representative to perform startup service.

1. Complete installation and startup checks in accordance with manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, controls, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that face-and-bypass dampers provide full face flow.
7. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
8. Comb coil fins for parallel orientation.
9. Verify that proper thermal-overload protection is installed for electric heaters.
10. Install new, clean filters.

11. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.
12. <**Insert requirement**>.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.[**Replace fan and motor pulleys as required to achieve design conditions.**]
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.
4. <**Insert requirement**>.

C. Heat Wheel Startup Service:

1. After field installation is complete, a final checkout and startup shall be completed to ensure proper purge adjustment, seal adjustment, control settings, and other key operational functions.
2. Service shall be completed by trained factory service personnel employed by heat wheel manufacturer.
3. Submit a report summarizing findings, adjustments made, and final settings.

3.9 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

C. Before turning equipment over to Owner for use, adjust air-handling unit components that require further adjustment for proper operation. Consult air-handling unit manufacturer for instruction.

D. Occupancy Adjustments: When requested within [**12**] <**Insert number**> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <**Insert number**> visits to Project during other-than-normal occupancy hours for this purpose.

E. Seasonal Adjustments: Make seasonal visits during warranty period to inspect and review operation of equipment. Make necessary adjustments for components observed to require adjustments for proper operation. Prepare and submit a report to Owner documenting each visit, observations, and any adjustments made.

3.10 CLEANING

A. Cleaning Schedule: After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems, and after completing startup service, and immediately before Owner use, clean air-handling units to remove foreign material and construction dirt and dust.

B. Unit Interior: Clean air-handling units internally to factory clean condition. Remove foreign material and construction debris, dirt, and dust.

1. Vacuum clean with HEPA-filtered vacuum and then wipe down with cleaning solution.
2. Clean casing floors, roofs, wall surfaces, access doors, and panels.
3. Clean all internal components, such as, coils, dampers, filter frames, fans, and motors.
4. Clean light fixtures and control devices.

C. Unit Exterior: Clean external surfaces of air-handling units to factory clean condition. Remove foreign material and construction debris, dirt, and dust. Vacuum clean with HEPA-filtered vacuum and then wipe down all surfaces with cleaning solution.

D. Cleaning Materials: Use cleaning materials and products recommended in writing by air-handling unit manufacturer.

E. Acceptance: Following unit cleaning, submit a written request for review and [**Owner**]acceptance. Acceptance for cleaning of air-handling units [**with absolute filters**]must pass a white glove test.

3.11 FIELD QUALITY CONTROL

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory service representative to test and inspect components, assemblies, and equipment installations, including connections.

C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**].

1. After field piping connections are complete, test [**hydronic**] [**and**] [**steam**] coils and connections for leaks.
2. Charge refrigerant coils with refrigerant and test for leaks.
3. Field-Assembly Supervision: Instruct Installer and supervise field installation of [**first**] <**Insert quantity**> air-handling unit(s) shipped in multiple pieces for field assembly.
4. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Field Casing Leakage Test:

1. Perform leak testing of air-handling units that include field assembly of multiple sections. Air-handling units that are shipped and installed as a single piece do not require field testing.
2. Leak test [**one**] <**Insert value**> air-handling unit(s) of each unique size and arrangement randomly selected by [**Architect**] [**Commissioning Agent**] [**Owner**].

3. Follow procedures complying with ASHRAE 111.
4. Assembled air-handling units shall satisfy leakage criteria indicated. Modify air-handling units that fail to satisfy criteria and retest. For every air-handling unit that fails test, another air-handling unit shall be tested until all air-handling units tested pass leakage criteria on first attempt.
5. Submit a test report for each test indicating test equipment, procedures, results, date and time, and full name of personnel performing tests and witnesses.
6. Test report shall be in accordance with ASHRAE 111.
7. Witness Testing:

    a. Provide written notification at least [**30**] [**20**] <**Insert number**> business days in advance of testing.
    b. Testing shall be conducted in presence of testing and balancing agent.
    c. Other parties such as Architect, Commissioning Agent, and Owner shall be invited to witness testing with attendance being optional.

E. Field Fan Vibration Test:

1. Perform fan vibration testing for every one out of [**10**] <**Insert number**> air-handling unit fans randomly selected by [**Architect**] [**Commissioning Agent**] [**Owner**].
2. Test after air-handling unit installation is complete.
3. Three vibration readings shall be taken for each bearing in horizontal, vertical, and axial directions. Record each reading including vibration amplitude verses frequency.
4. Modify fans that fail to satisfy performance criteria and retest. For every fan that fails test, another fan shall be tested until all fans tested pass criteria on first attempt.
5. Submit a report for each fan tested indicating air-handling unit designation, fan designation, test equipment, procedures, results, date and time, and full name of personnel performing tests and witnesses.
6. Witness Testing:

    a. Provide written notification at least [**30**] [**20**] <**Insert number**> business days in advance of testing.
    b. Testing shall be conducted in presence of testing and balancing agent.
    c. Other parties such as Commissioning Agent, Architect, and Owner shall be invited to witness testing with attendance being optional.

F. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

G. Prepare test and inspection reports.

3.12 OPERATION DURING CONSTRUCTION

A. Operation of air-handling units for temporary cooling, heating, and ventilation is not allowed without Owner authorization.

1. Submit written request for Owner approval by signature with detailed description of operating procedures to be followed including, but not limited to, the following:

    a. Description of construction activities while units are operating.

b. Operation:

1) Beginning and ending calendar dates.
2) List each day during week.
3) List start and stop time and hours for each day.

c. Startup procedures and shut-down procedures.
d. Provisions for routine monitoring of unit operation.
e. Provisions to prevent and protect against damage to equipment due to adverse operation such as, low temperature, high temperature, over pressure, fire, smoke, electrical over- and undervoltage, and current and electrical fault.
f. Provisions and safeguards for filtration to keep inside of units from getting dirty.
g. Record keeping.

2. If approved by Owner, units used for temporary cooling, heating, and ventilation during and before interior finish work is complete shall include an unconditional complete unit labor and parts warranty to extend at least [**two**] <**Insert number**> years after the warranty indicated expires.
3. Interior and exterior of air-handling units shall be cleaned to a factory-cleaned condition and clean condition must be accepted by Owner.

B. Filtration during Temporary Use:

1. Protect air-handling system ducts (exhaust air, outdoor air, and return air) with temporary filters installed and supported to prevent filter media from collapse and bypass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV [**8**] [**11**] [**13**] <**Insert MERV**> in accordance with ASHRAE 52.2.
2. Protect air-handling units with open inlets that are not ducted with temporary filters installed and supported to prevent filter media from collapse and bypass of unfiltered air. Temporary media shall be installed at each inlet and shall have a published filtration efficiency of MERV [**8**] [**11**] [**13**] <**Insert MERV**> in accordance with ASHRAE 52.2.
3. Do not operate air-handling units until both temporary and scheduled permanent air-handling unit particulate filters are in place. Temporary filters must be installed upstream of permanent filters while units are operating.
4. Replace temporary and permanent filters used during construction when dirty. After end of temporary use, replace permanent filters with new, clean filters before beginning testing, adjusting, and balancing.

C. Comply with SMACNA 008, "IAQ Guidelines for Occupied Buildings under Construction," for procedures to protect HVAC system.

3.13 DEMONSTRATION

A. Engage air-handling unit manufacturer [**employed training instructor**] [**or**] [**factory-authorized service representative**] to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

B. Training shall include, but not be limited to, procedures and schedules related to performance, safety, startup and shut down, troubleshooting, servicing, preventive maintenance, and how to obtain replacement parts.

1. Access Doors: Adjustment, gasket removal and replacement, handle removal and replacement, and spare parts.
2. Access Panels: Removal and replacement, adjustment, gasket removal and replacement, and spare parts.
3. Air Blenders: Cleaning, operation, removal, and replacement.
4. Coils: Cleaning, combing fins, draining, venting, removal, and replacement.
5. Controls: Calibration, cleaning, operation, service, removal and replacement, and spare parts.
6. Damper Assemblies: Cleaning, operation, service, removal and replacement, and spare parts.
7. Drain Pans: Cleaning, removal, and replacement.
8. Duct Silencers: Cleaning, removal, and replacement.
9. Electric Heaters: Cleaning, operation, service, removal and replacement, and spare parts.
10. Heat Wheels: Cleaning, operation, service, removal and replacement, and spare parts.
11. Fan and Motor Assemblies: Cleaning, operation, removal and replacement, service, and spare parts.
12. Filters: Operation, removal and replacement, frame gasket removal and replacement, clip removal and replacement, and spare parts.
13. Fixed Plate heat Exchangers: Cleaning, removal, and replacement.
14. Heat Pipe Heat Exchangers: Cleaning, combing fins, removal, and replacement.
15. Humidifiers: Cleaning, operation, service, removal and replacement, and spare parts.
16. UV-C Lamp Systems: Cleaning, operation, service, removal and replacement, and spare parts.
17. Lights, Receptacles, and Switches: Cleaning, operation, service, removal and replacement, and spare parts.
18. <**Insert requirement**>.

C. Instructor:

1. Instructor shall be factory trained and certified by air-handling unit manufacturer with current training on equipment installed.
2. Instructor's credentials shall be submitted for review by [**Architect**] [**Commissioning Agent**] [**Owner**] before scheduling training.
3. Instructor(s) [**primary**] [**sole**] job responsibility shall be Owner training.
4. Instructor(s) shall have not less than [**three**] <**Insert number**> years of training experience with air-handling unit manufacturer and past training experience on at least [**three**] <**Insert number**> projects of comparable size and complexity.

D. Schedule and Duration:

1. Schedule training with Owner at least [**20**] <**Insert number**> business days before first training session.
2. Training shall occur before Owner occupancy.
3. Training shall be held at mutually agreed date and time during normal business hours.
4. Each training day shall not exceed [**eight**] <**Insert number**> hours of training. Daily training schedule shall allow time for a [**one**] <**Insert number**>-hour lunch period and

[**15**] <**Insert number**>-minute break after every [**two**] <**Insert number**> hours of training.

5. Perform not less than [**eight**] [**16**] [**24**] <**Insert number**> hours of training.

E. Location: Owner to provide a suitable on-site location to host classroom training.

F. Training Attendees: Assume [**three**] <**Insert number**> people.

G. Training Attendance Records: For record purposes, document training attendees at start of each new training session. Record date, time, brief description of training covered during the session, attendee's name, signature, phone number, and e-mail address. Submit scanned copy of sign-in sheet to Owner for each training session.

H. Training Format: Individual training modules toinclude classroom training followed by hands-on field demonstration and training.

I. Training Materials: Provide training materials in electronic format to each attendee.

1. Include instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.

J. Training Video Recording: Video record each classroom training session and submit an electronic copy to Owner before requesting Owner acceptance of training.

K. Written Acceptance: Obtain [**Architect**] [**Commissioning Agent**] [**or**] [**Owner**] written acceptance that training is complete and requirements indicated have been satisfied.

END OF SECTION 237313.19

SECTION 238123.13 - COMPUTER-ROOM AIR-CONDITIONERS, CEILING-MOUNTED UNITS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

This Section includes requirements for a Sustainable Rating System. However, equipment specified in this Section may not qualify for prerequisites and credits. Verify, with manufacturers, that the requirements for prerequisites and credits can be met. To achieve prerequisites and obtain credits, HVAC system design alternatives that do not include computer-room air conditioners may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes ceiling-mounted, computer-room air conditioners.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

A. COP: Coefficient of performance.

B. EER: Energy efficiency ratio.

C. SCR: Silicon-controlled rectifier.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include material descriptions, dimensions of individual components and profiles, and finishes for computer-room air-conditioning units.
2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for unit energy performance.>
2. <Double click to insert sustainable design text for HVAC units.>
3. <Double click to insert sustainable design text for ASHRAE 62.1.>

C. Shop Drawings: For computer-room air conditioners.

1. Include plans, elevations, sections, and attachment details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.

D. Color Samples: For unit cabinet, discharge grille, and exterior louver and for each color and texture specified.

1.5 INFORMATIONAL SUBMITTALS

Retain "Coordination Drawings" Paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, using input from installers of the items involved.

Retain "Seismic Qualification Certificates" Paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

B. Seismic Qualification Certificates: For computer-room air conditioners, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Retain "Field quality-control reports" Paragraph below if Contractor is responsible for field quality-control testing and inspecting.

C. Field quality-control reports.

D. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For computer-room air conditioners to include in emergency, operation, and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fan Belts: [**One**] <**Insert number**> set(s) for each belt-driven fan.
2. Filters: [**One**] <**Insert number**> set(s) of filters for each unit.

1.8 WARRANTY

When warranties are required, verify with Owner's counsel that warranties stated in this article are not less than remedies available to Owner under prevailing local laws.

A. Special Warranty: Manufacturer agrees to repair or replace components of computer-room air conditioners that fail in materials or workmanship within specified warranty period.

Verify available warranties and warranty periods for units and components.

1. Warranty Period for Compressors: Manufacturer's standard, but not less than [**five**] [**10**] <**Insert number**> years from date of Substantial Completion.
2. Warranty Period for Humidifiers: Manufacturer's standard, but not less than [**three**] <**Insert number**> years from date of Substantial Completion.
3. Warranty Period for Control Boards: Manufacturer's standard, but not less than [**three**] <**Insert number**> years from date of Substantial Completion.

PART 2 - PRODUCTS

Manufacturers and products listed in SpecAgent and Masterworks Paragraph Builder are neither recommended nor endorsed by the AIA or AVITRU. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications. For definitions of terms and requirements for Contractor's product selection, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.2 PERFORMANCE REQUIREMENTS

Retain "Seismic Performance" Paragraph below with "Seismic Qualification Certificates" Paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

A. Seismic Performance: Computer-room air-conditioners, ceiling-mounted units shall withstand the effects of earthquake motions determined according to [**ASCE/SEI 7**] <**Insert requirement**>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. ASHRAE Compliance:

1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."

"ASHRAE Compliance" Subparagraph below may be required to comply with Project requirements or authorities having jurisdiction. Verify, with manufacturers, availability of units with components and features that comply with these requirements.

2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."

"ASHRAE/IES Compliance" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction.

D. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1.

E. ASME Compliance: Fabricate and label water-cooled condenser shell to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.

2.3 MANUFACTURED UNITS

A. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls.

Retain one of three "Mounting Configuration" subparagraphs below. Delete all three if more than one mounting configuration is required and units are scheduled on Drawings.

1. Mounting Configuration: Exposed in the space.
2. Mounting Configuration: Fit T-bar in lay-in ceiling opening.
3. Mounting Configuration: Concealed above a hard ceiling.

B. Cabinet: Galvanized steel serviceable from one side, with baked-enamel finish, insulated with 1/2-inch-thick duct liner, and mounting bracket attached to the unit.

Retain first subparagraph below for units where grilles are available, usually 1.5 tons (5 kW) and smaller. Retain second subparagraph for ducted units. Retain third subparagraph for units with air distribution plenum, usually 3 tons (10 kW) and smaller. Retain fourth subparagraph for units less than 3 tons (10 kW). Retain fifth subparagraph for units 5 tons (18 kW) and larger. Retain sixth subparagraph for high static blower assembly.

1. Integral factory-supplied supply and return grille to fit ceiling grid kit of 24 by 48 inches, with filter.
2. Unit with supply and return collars for ducting in the field.
3. Unit with 24-by-48-inch air distribution plenum, with integral MERV 8 filter and three-way air distribution.
4. Unit with two-speed, centrifugal direct-drive fan.
5. Unit with single-speed, centrifugal belt-driven fan.
6. Unit with high static blower assembly consisting of field-attached blower box with double-inlet, centrifugal belt-driven fan; with single-speed motor mounted on an adjustable base, and providing up to 2 inches wc of external pressure.
7. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. Supply-Air Fan:

Retain one of two subparagraphs below. Plug/plenum fans are only available on downflow models.

1. Forward curved, double width, double inlet, centrifugal, with adjustable V-belt drive.
2. Plug/plenum, single inlet, direct drive, electronically commutated, and variable speed.

Retain "Refrigeration System" Paragraph below for units with direct-expansion refrigerant cooling.

D. Refrigeration System:

1. Compressor: Scroll, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
2. Refrigeration Circuit Components:

   a. Low-pressure switch.
   b. Manually reset, high-pressure switch.

c. Thermal-expansion valve with external equalizer.
d. Sight glass with moisture indicator.
e. Service shutoff valves.
f. Charging valves.
g. Hot-gas bypass.
h. Refrigerant charge.

Retain "Refrigerant" Subparagraph below to require a specific refrigerant type; delete if any refrigerant type is acceptable.

3. Refrigerant: [**R-407C**] [**or**] [**R-410A**] <**Insert type**>.
4. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins.
5. Refrigerant line sets precharged in lengths of [**15 feet**] [**30 feet**] and of sufficient length to serve the unit from its condensing unit.
6. Refrigerant line-sweat-adapter kit to permit field brazing of refrigerant lines.

a. Mount stainless-steel drain pan [**complying with ASHRAE 62.1**] [**and**] [**having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir**] under coil assembly.

Retain one of first two subparagraphs below for integral, water-cooled or remote, air-cooled refrigerant condenser.

7. Integral, Water-Cooled Refrigerant Condenser: [**Coaxial, counterflow, tube-in-tube**] [**Brazed-plate**] type with liquid-line stop valve and head-pressure-actuated, water-regulating valve.

a. Cooling Medium: [**Water**] [**Glycol solution**].

8. Remote, Air-Cooled Refrigerant Condenser: Integral, copper-tube aluminum-fin coil with direct-drive, [**propeller**] [**centrifugal**] fan.
9. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

Retain "Hydronic Cooling Coil" Paragraph below for units with external or supplementary (seasonal) cooling. Units can be chilled-water cooled without a refrigeration system. If retaining paragraph below, delete "Refrigeration System" Paragraph.

E. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with two-way control valve.

1. Cooling Medium: [**Water**] [**Glycol solution**].
2. Mount stainless-steel drain pan [**complying with ASHRAE 62.1**] [**and**] [**having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir**] under coil assembly.

Retain "Hot-Water Reheat" Paragraph below for units with reheat.

F. Hot-Water Reheat: Copper-tube, aluminum-fin coil with two-way, modulating control valve and cleanable Y-strainer.

Retain first two paragraphs below for units with glycol-solution-cooled condenser or with supplementary cooling coil.

G. Remote, Air-Cooled, Glycol-Solution Cooler:

1. Corrosion-resistant cabinet.
2. Copper-tube aluminum-fin coil.
3. Direct-drive propeller fan with fan guards.
4. Single-phase motors with internal overload protection.

H. Glycol-Solution Pump Package:

1. Weatherproof and vented enclosure of enameled, galvanized steel on structural base frame containing centrifugal pump with mechanical seal.
2. Piping: Interconnecting piping, to and from remote, air-cooled glycol-solution cooler, with shutoff valves, flow switches, unions, and pressurized expansion tank with air purge vent and system-charging connection.
3. Glycol: Inhibited ethylene glycol and water solution mixed 50:50, suitable for operating temperature of minus 40 deg F.

Retain "Electric-Resistance Reheat Coil" Paragraph below for units with reheat.

I. Electric-Resistance Reheat Coil:

Retain first subparagraph below for units with heating. Retain fourth subparagraph for more precise control; otherwise, delete. SCR heating is less efficient because the compressor is locked on with this type of heating.

1. Finned-tube electric elements with contactor.
2. Dehumidification relay.
3. High-temperature-limit switches.
4. SCR to proportionally control the reheat elements providing precise temperature control.

J. Filter: 1-inch-thick, disposable, glass-fiber media.

Retain "Initial Resistance" and "Recommended Final Resistance" subparagraphs below if units are not scheduled on Drawings.

1. Initial Resistance: <**Insert number**> inches wg.
2. Recommended Final Resistance: <**Insert number**> inches wg.

Retain one of either "Pre-Filter Minimum Efficiency Reporting Value and Average Arrestance" or "Pre-Filter Minimum Efficiency Reporting Value" subparagraphs below. Retain first subparagraph if requiring MERV 1, 2, 3, or 4 and if information is not scheduled on Drawings. Retain second subparagraph below if inserting requirements for MERV 5 and higher and if information is not scheduled on Drawings. LEED 2009 IEQ Prerequisite 1 and LEED v4 EQ Prerequisite, "Minimum Indoor Air Quality Performance," require compliance with ASHRAE 62.1 (2007 and 2010 versions, respectively), which requires a MERV rating of 6 or higher for service to occupied spaces. LEED 2009 IEQ Credit 5 and LEED v4 IEQ Credit, "Enhanced Indoor Air Quality Strategies," require MERV 13 or higher. Insert values appropriate to Project sustainability goals.

3. Pre-Filter Minimum Efficiency Reporting Value and Average Arrestance:

a. MERV Rating: [**MERV 1**] [**MERV 2**] [**MERV 3**] [**MERV 4**] <**Insert value**> and corresponding average arrestance according to ASHRAE 52.2.

4. Pre-Filter Minimum Efficiency Reporting Value:

a. [**MERV 6**] <**Insert value**> according to ASHRAE 52.2.

5. Filter Minimum Efficiency Reporting Value:

a. MERV Rating: [**MERV 6**] [**MERV 13**] <**Insert value**> according to ASHRAE 52.2.

Retain "Electrode Steam Humidifier" Paragraph below if this optional feature is required.

K. Electrode Steam Humidifier: Self-contained, microprocessor-controlled unit with disposable, polypropylene-plastic cylinders, and having field-adjustable steel electrodes and stainless-steel steam dispersion tube.

1. Plumbing Components and Valve Bodies: Plastic, linked by flexible rubber hosing, with water fill with air gap and solenoid valve incorporating built-in strainer, pressure-reducing and flow-regulating orifice, and drain with integral air gap.
2. Control: Fully modulating to provide gradual modulation from zero to 100 percent capacity with field-adjustable maximum capacity; with high-water probe.
3. Drain Cycle: Field-adjustable drain duration and drain interval.

Retain "Disconnect Switch" Paragraph below to require unit manufacturer to provide a factory-installed disconnect switch. Standard unit does not come with disconnect switch. Switches provided by manufacturers may not be of quality required for Project. Coordinate with Section 262816 "Enclosed Switches and Circuit Breakers."

L. Disconnect Switch: Non-automatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.

M. Single point power kit permitting single electrical feed to the evaporator and condensing unit of a close-coupled system.

N. Epoxy-coated, step-down transformer suitable for mounting on the outdoor condensing unit to provide it with 277-V input power.

O. Control System:

1. Microprocessor [**unit**] [**remote**]-mounted panel.
2. Fan contactor.
3. Compressor contactor.
4. Compressor start capacitor.
5. Control transformer with circuit breaker.
6. Solid-state temperature-[**and humidity**-]control modules.
7. Humidity contactor.
8. Time-delay relay.
9. Heating contactor.
10. Smoke sensor.

11. Filter clog switch.
12. Alarm contacts.
13. High-temperature thermostat.
14. Solid-state, wall-mounted control panel with start-stop switch[**, adjustable humidity set point,**] [**remote temperature sensors**] [**remote humidity sensors**] and adjustable temperature set point.
15. Remote panel to monitor and change temperature and humidity set points and sensitivities of the unit and unit alarms.

P. Fan Motors:

Default motor characteristics are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

    a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load does not require motor to operate in service factor range above 1.0.
    b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

If unique characteristics are required for motors in this Section, insert paragraphs below.

    c. <**Insert unique motor characteristics**>.

2.4 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of computer-room air conditioner, delete this article and schedule units on Drawings.

Retain "Supply-Air Fan" Paragraph below for floor-mounted units; delete for ceiling-mounted and console units.

A. Supply-Air Fan:

1. Airflow: <**Insert cfm**>.
2. Minimum Static Pressure: <**Insert inches wg**>.
3. Motor Size: <**Insert number**> hp.

Retain one of first two paragraphs below. Retain first paragraph for units with a refrigeration package; retain second for hydronic cooling coils.

B. Refrigeration System:

1. Unit Energy Efficiency: [**COP**] [**EER**].
2. Refrigerant Compressor:

    a. Total Unit Cooling Capacity: <**Insert Btu/h**>.
    b. Sensible Unit Cooling Capacity: <**Insert Btu/h**>.

c. Number of Compressors: [**One**] [**Two**] <**Insert number**>.
d. Motor Size: <**Insert number**> hp.

3. Refrigerant Evaporator Coil:

a. Cooling Capacity: <**Insert Btu/h**>.
b. Entering-Air Dry-Bulb Temperature: <**Insert deg F**>.
c. Entering-Air Wet-Bulb Temperature: <**Insert deg F**>.
d. Leaving-Air Dry-Bulb Temperature: <**Insert deg F**>.
e. Leaving-Air Wet-Bulb Temperature: <**Insert deg F**>.

Retain first subparagraph below for water-cooled units.

4. Water-Cooled Refrigerant Condenser:

a. Cooling Capacity: <**Insert Btu/h**>.
b. Condenser Water Flow: <**Insert gpm**>.
c. Cooling Medium: [**Water**] [**Glycol solution**].
d. Entering-Water Temperature: <**Insert deg F**>.
e. Fluid Pressure Drop: <**Insert feet of head**>.

Retain subparagraph below for air-cooled units.

5. Air-Cooled Refrigerant Condenser:

a. Cooling Capacity: <**Insert Btu/h**>.
b. Entering-Air Temperature: <**Insert deg F**>.
c. Number of Condenser Fan Motors: <**Insert number**>.
d. Condenser Fan Motors: <**Insert number**> hp.

Retain first paragraph below for hydronic cooling units.

C. Hydronic Cooling Coil:

1. Cooling Coil Capacity: <**Insert Btu/h**>.
2. Entering-Air Dry-Bulb Temperature: <**Insert deg F**>.
3. Entering-Air Wet-Bulb Temperature: <**Insert deg F**>.
4. Leaving-Air Dry-Bulb Temperature: <**Insert deg F**>.
5. Leaving-Air Wet-Bulb Temperature: <**Insert deg F**>.
6. Fluid Flow: <**Insert gpm**>.
7. Entering-Fluid Temperature: <**Insert deg F**>.
8. Fluid Pressure Drop: <**Insert feet of head**>.
9. Cooling Medium: [**Water**] [**Glycol solution**].

Retain first paragraph below for units with a remote, air-cooled, glycol-solution cooler.

D. Remote, Air-Cooled, Glycol-Solution Cooler:

1. Cooling Coil Capacity: <**Insert Btu/h**>.
2. Entering-Air Temperature: <**Insert deg F**>.
3. Leaving-Air Temperature: <**Insert deg F**>.

4. Glycol Flow: <**Insert gpm**>.
5. Entering-Glycol Temperature: <**Insert deg F**>.
6. Number of Fans: <**Insert number**>.
7. Fan Motors: <**Insert number**> hp.
8. Number of Pumps: <**Insert number**>.
9. Pump Motors: <**Insert number**> hp.

Retain first paragraph below for units with hydronic reheating coils.

E. Hydronic Reheating Coil:

1. Total: <**Insert Btu/h**>.
2. Entering-Air Dry-Bulb Temperature: <**Insert deg F**>.
3. Leaving-Air Dry-Bulb Temperature: <**Insert deg F**>.
4. Water Flow: <**Insert gpm**>.
5. Entering-Water Temperature: <**Insert deg F**>.
6. Leaving-Water Temperature: <**Insert deg F**>.
7. Fluid Pressure Drop: <**Insert feet of head**>.

Retain first paragraph below for units with electric-resistance reheating coils.

F. Electric-Resistance Reheating Coil:

1. Total Capacity: <**Insert kilowatts**>.
2. Stages of Heating: [**1**] [**2**] <**Insert number**>.

Retain first paragraph below for units with humidifiers.

G. Humidifier:

1. Total: <**Insert lb/h**>.
2. Input: <**Insert Btu/h**>.

H. Electrical Characteristics:

1. Volts: [**120**] [**208**] [**240**] [**277**] [**480**] <**Insert value**>.
2. Phase: [**Single**] [**Three**].
3. Hertz: 60.
4. Full-Load Amperes: <**Insert value**>.
5. Minimum Circuit Ampacity: <**Insert value**>.
6. Maximum Overcurrent Protection: <**Insert amperage**>.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for hydronic piping systems to verify actual locations of piping connections before equipment installation.

C. Examine walls, floors, and roofs for suitable conditions where computer-room air conditioners will be installed.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Layout and install computer-room air conditioners and suspension system coordinated with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.

B. Install computer-room air conditioners coordinated with computer-room access flooring Installer.

C. Install computer-room air conditioners level and plumb, maintaining manufacturer's recommended clearances.[**Install according to AHRI Guideline B.**]

Retain one or more of four paragraphs below. Coordinate with Drawings and Sections specifying vibration and seismic controls. Retain or insert amount of required deflection.

D. Suspended Computer-Room Air Conditioners: Install using continuous-thread hanger rods and [**elastomeric hangers**] [**spring hangers**] [**spring hangers with vertical-limit stop**] of size required to support weight of computer-room air conditioner.

1. Comply with requirements for vibration isolation devices specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**] Fabricate brackets or supports as required.
2. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

Coordinate sizes and locations of concrete bases with actual equipment provided.

E. Air-Cooled Refrigerant Condenser Mounting: Install using [**elastomeric pads**] [**elastomeric mounts**] [**restrained spring isolators**] <**Insert device**> on concrete base. Comply with requirements for vibration isolation devices specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]

1. Minimum Deflection: [**1/4 inch**] [**1 inch**] <**Insert dimension**>.

F. Remote, Air-Cooled, Glycol-Solution Cooler Mounting: Install using [**elastomeric pads**] [**elastomeric mounts**] [**restrained spring isolators**] <**Insert device**> on concrete base. Comply with requirements for vibration isolation devices specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]

1. Minimum Deflection: [**1/4 inch**] [**1 inch**] <**Insert dimension**>.

Coordinate sizes and locations of concrete bases with actual equipment provided.

G. Glycol-Solution Pump Package Mounting: Install using [**elastomeric pads**] [**elastomeric mounts**] <**Insert device**>. Comply with requirements for vibration isolation devices specified in [**Section 230548 "Vibration and Seismic Controls for HVAC."**] [**Section 230548.13 "Vibration Controls for HVAC."**]

3.3 CONNECTIONS

Coordinate piping installations and specialty arrangements with Drawings and with requirements specified in piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

A. Piping installation requirements are specified in other heating, ventilating, and air-conditioning Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to computer-room air conditioners, allow space for service and maintenance.

C. Water and Drainage Connections: Comply with applicable requirements in Section 221116 "Domestic Water Piping." Provide adequate connections for water-cooled units, condensate drain, and humidifier flushing system.

Retain "Hot-Water Heating Piping" Paragraph below for units with hot-water coils.

D. Hot-Water Heating Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Provide shutoff valves in inlet and outlet piping to heating coils.

E. Condenser-Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Provide shutoff valves in water inlet and outlet piping on water-cooled units.

F. Refrigerant Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping." Provide shutoff valves and piping.

3.4 FIELD QUALITY CONTROL

Retain "Testing Agency," "Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. If retaining second option in "Testing Agency" Paragraph or if retaining "Manufacturer's Field Service" or "Perform the following tests and inspections" Paragraph, retain "Field quality-control reports" Paragraph in "Informational Submittals" Article.

A. Testing Agency: [**Owner will engage**] [**Engage**] a qualified testing agency to perform tests and inspections.

Retain "Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:

1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
2. After installing computer-room air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

D. Computer-room air conditioners will be considered defective if they do not pass tests and inspections.

E. Prepare test and inspection reports.

F. After startup service and performance test, change filters and flush humidifier.

3.5 ADJUSTING

A. Adjust initial temperature[**and humidity**] set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

C. Occupancy Adjustments: When requested within [**12**] <**Insert number**> months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [**two**] <**Insert number**> visits to Project during other-than-normal occupancy hours for this purpose.

3.6 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain computer-room air conditioners.

END OF SECTION 238123.13

SECTION 238239.19 - WALL AND CEILING UNIT HEATERS

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Content Requests:

<Double click here to submit questions, comments, or suggested edits to this Section.>

This Section includes requirements for sustainable design systems. However, equipment specified in this Section may not meet requirements of those systems. Verify, with manufacturers, that the requirements can be met. To comply, HVAC system design alternatives that do not include wall and ceiling unit heaters may be required.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes wall and ceiling heaters with propeller fans and electric-resistance heating coils.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated capacities, operating characteristics, furnished specialties, and accessories.

B. Sustainable Design Submittals:

1. <Double click to insert sustainable design text for HVAC units.>

C. Shop Drawings:

1. Include plans, elevations, sections, and details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include details of anchorages and attachments to structure and to supported equipment.
4. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.
5. Wiring Diagrams: Power, signal, and control wiring.

Retain "Samples" Paragraph below for single-stage Samples, with a subordinate list if applicable.

D. Samples: For each exposed product and for each color and texture specified.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For wall and ceiling unit heaters to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

See Editing Instruction No. 1 in the Evaluations for cautions about named manufacturers and products. For an explanation of options and Contractor's product selection procedures, see Section 016000 "Product Requirements."

2.1 MANUFACTURERS

A. <Double click here to find, evaluate, and insert list of manufacturers and products.>

2.2 DESCRIPTION

A. Assembly including chassis, electric heating coil, fan, motor, and controls. Comply with UL 2021.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 CABINET

A. Front Panel: [**Stamped-steel louver**] [**Extruded-aluminum bar grille**], with removable panels fastened with tamperproof fasteners.

B. Finish: Baked enamel over baked-on primer with manufacturer's [**standard**] [**custom**] color selected by Architect, applied to factory-assembled and -tested wall and ceiling heaters before shipping.

"Airstream Surfaces" Paragraph below may be required to comply with Project requirements or authorities having jurisdiction and is required for sustainable design systems.

C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Surface-Mounted Cabinet Enclosure: Steel with finish to match cabinet.

2.4 COIL

A. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in corrosion-resistant metallic sheath. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware, and limit controls for high-temperature protection.[**Provide integral circuit breaker for overcurrent protection.**]

2.5 FAN AND MOTOR

A. Fan: Aluminum propeller directly connected to motor.

Motor characteristics such as NEMA designation, temperature rating, service factor, enclosure type, and efficiency are specified in Section 230513 "Common Motor Requirements for HVAC Equipment." If different characteristics are required, insert paragraphs below to suit Project.

B. Motor: Permanently lubricated[**, multispeed**]. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.6 CONTROLS

A. Controls: Unit-mounted thermostat.[**Low-voltage relay with transformer kit.**]

B. Electrical Connection: Factory wire motors and controls for a single field connection[**with disconnect switch**].

2.7 CAPACITIES AND CHARACTERISTICS

If Project has more than one type or configuration of heater, delete this article and schedule wall and ceiling heaters on Drawings.

A. Airflow: <**Insert cfm**>.

B. Fan Speed: <**Insert rpm**>.

C. Heating Coil: <**Insert kilowatts**>.

D. Electrical Characteristics for Single-Point Connection:

1. Volts: <**Insert value**>.
2. Phase: <**Insert value**>.
3. Hertz: <**Insert value**>.
4. Full-Load Amperes: <**Insert value**>.
5. Minimum Circuit Ampacity: <**Insert value**>.
6. Maximum Overcurrent Protection: <**Insert amperage**>.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive wall and ceiling unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for electrical connections to verify actual locations before unit-heater installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install wall and ceiling unit heaters to comply with NFPA 90A.

B. Install wall and ceiling unit heaters level and plumb.

Retain first paragraph below if controls are provided by unit-heater manufacturer. To comply with requirements of the Americans with Disabilities Act, verify mounting height with authorities having jurisdiction.

C. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.

D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

END OF SECTION 238239.19

SECTION 26 0519

LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Building wires and cables rated 600 V and less.
2. Connectors, splices, and terminations rated 600 V and less.

B. Related Requirements:

1. Section 26 0523 "Control-Voltage Electrical Power Cables" for control systems communications cables and Classes 1, 2 and 3 control cables.
2. Section 27 1500 "Communications Horizontal Cabling" for cabling used for voice and data circuits.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 CONDUCTORS AND CABLES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Alpha Wire Company.
2. Belden Inc.
3. Cerro Wire LLC.
4. Cooper Industries, Inc.
5. Encore Wire Corporation.
6. General Cable Technologies Corporation.
7. General Cable; General Cable Corporation.
8. Senator Wire & Cable Company.
9. Service Wire Co.
10. Southwire Company.
11. Thomas & Betts Corporation, A Member of the ABB Group.

B. Copper Conductors: Comply with NEMA WC 70/ICEA S-95-658.

C. Conductor Insulation: Comply with NEMA WC 70/ICEA S-95-658 for Type THHN/THWN-2 and Type SO.

2.2 CONNECTORS AND SPLICES

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

1. 3M.
2. AFC Cable Systems, Inc.
3. Gardner Bender.
4. Hubbell Power Systems, Inc.
5. Ideal Industries, Inc.
6. ILSCO.
7. NSi Industries LLC.
8. O-Z/Gedney; a brand of Emerson Industrial Automation.
9. Tyco Electronics Corp.

B. Description: Factory-fabricated connectors and splices of size, ampacity rating, material, type, and class for application and service indicated.

1. Expandable steel spring and polypropylene body type connectors and wire nuts for wire sizes up to an including No. 10 AWG.
2. Bolt type connectors or mechanical compression crimp type for wire sizes No. 8 AWG and larger. Cover connectors with three layers of 600 volt tape or heat shrinkable insulation equivalent to 150% conductor insulation.

2.3 SYSTEM DESCRIPTION

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Comply with NFPA 70.

PART 3 - EXECUTION

3.1 CONDUCTOR MATERIAL APPLICATIONS

A. Feeders: Copper. Solid for No. 10 AWG and smaller; stranded for No. 8 AWG and larger.

B. Branch Circuits: Copper. Solid for No. 10 AWG and smaller; stranded for No. 8 AWG and larger, except VFC cable, which shall be extra flexible stranded.

3.2 CONDUCTOR INSULATION AND MULTICONDUCTOR CABLE APPLICATIONS AND WIRING METHODS

A. Service Entrance: Type THHN/THWN-2, single conductors in raceway.

B. Exposed Feeders: Type THHN/THWN-2, single conductors in raceway.

C. Feeders Concealed in Ceilings, Walls, Partitions, and Crawlspaces: Type THHN/THWN-2, single conductors in raceway.

D. Feeders Concealed in Concrete, below Slabs-on-Grade, and Underground: Type THHN/THWN-2, single conductors in raceway.

E. Exposed Branch Circuits, Including in Crawlspaces: Type THHN/THWN-2, single conductors in raceway.

F. Branch Circuits Concealed in Ceilings, Walls, and Partitions: Type THHN/THWN-2, single conductors in raceway.

G. Branch Circuits Concealed in Concrete, below Slabs-on-Grade, and Underground: Type THHN/THWN-2, single conductors in raceway.

H. Cord Drops and Portable Appliance Connections: Type SO, hard service cord with stainless-steel, wire-mesh, strain relief device at terminations to suit application.

I. Minimum wire size shall be No. 12 except for internal fixture wire which shall be minimum size of No. 14 type SF, SFF, PF, PFF or TFN, 600 volt.

J. All branch circuit wiring and feeder cables for circuits over 20 amps shall be sized as noted on the drawings. If size is not specifically noted, size all branch circuit wiring and feeder cables in accordance with the National Electrical Code.

3.3 INSTALLATION OF CONDUCTORS AND CABLES

A. Conceal cables in finished walls, ceilings, and floors unless otherwise indicated.

B. Complete raceway installation between conductor and cable termination points according to Section 260533 "Raceways and Boxes for Electrical Systems" prior to pulling conductors and cables.

C. Use manufacturer-approved pulling compound or lubricant where necessary; compound used must not deteriorate conductor or insulation. Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.

D. Use pulling means, including fish tape, cable, rope, and basket-weave wire/cable grips, that will not damage cables or raceway.

E. Install exposed cables parallel and perpendicular to surfaces of exposed structural members, and follow surface contours where possible.

F. Support cables according to Section 260529 "Hangers and Supports for Electrical Systems."

3.4 CONNECTIONS

A. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A-486B.

B. Make splices, terminations, and taps that are compatible with conductor material and that possess equivalent or better mechanical strength and insulation ratings than unspliced conductors.

C. Splices and taps in conductors shall be as few in number as practicable.

D. Splices and taps shall be so made that they have an electrical resistance not in excess of that of 2’ of the conductor.

1. Use oxide inhibitor in each splice, termination, and tap for aluminum conductors.

E. Wiring at Outlets: Install conductor at each outlet, with at least 6 inches of slack.

F. Neutral conductors in outlet boxes at receptacles shall be jointed and pigtailed to the outlet. The removal of a receptacle from the circuit shall not affect the continuity of the neutral conductor.

3.5 IDENTIFICATION

A. Identify and color-code conductors and cables according to Section 260553 "Identification for Electrical Systems."

B. Identify each spare conductor at each end with identity number and location of other end of conductor, and identify as spare conductor.

3.6 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.7 FIRESTOPPING

A. Apply firestopping to electrical penetrations of fire-rated floor and wall assemblies to restore original fire-resistance rating of assembly according to Section 078413 "Penetration Firestopping."

3.8 FIELD QUALITY CONTROL

A. Perform the following tests and inspections:

1. After installing conductors and cables and before electrical circuitry has been energized, test service entrance and feeder conductors for compliance with requirements. Delete first subparagraph below if deleting options in subparagraph above.
2. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.

B. Cables will be considered defective if they do not pass tests and inspections.

END OF SECTION

SECTION 26 0523

CONTROL-VOLTAGE ELECTRICAL POWER CABLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Low-voltage control cabling.
2. Control-circuit conductors.
3. Identification products.

1.3 DEFINITIONS

A. EMI: Electromagnetic interference.

B. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control and signaling power-limited circuits.

C. Plenum: A space forming part of the air distribution system to which one or more air ducts are connected. An air duct is a passageway, other than a plenum, for transporting air to or from heating, ventilating, or air-conditioning equipment.

D. RCDD: Registered Communications Distribution Designer.

E. UTP: Unshielded twisted pair.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 LOW-VOLTAGE CONTROL CABLE

A. Paired Cable: NFPA 70, Type CMG.

1. One pair, twisted, No. 18 AWG, stranded (19x30) tinned-copper conductors.
2. PVC insulation.
3. Unshielded.
4. PVC jacket.
5. Flame Resistance: Comply with UL 1685.

2.3 CONTROL-CIRCUIT CONDUCTORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Encore Wire Corporation.
2. General Cable; General Cable Corporation.
3. Service Wire Co.

B. Class 1 Control Circuits: Stranded copper, Type THHN/THWN-2, complying with UL 83 in raceway.

C. Class 2 Control Circuits: Stranded copper, Type THHN/THWN-2, complying with UL 83 in raceway.

D. Class 3 Remote-Control and Signal Circuits: Stranded copper, Type THHN/THWN-2, complying with UL 83 in raceway.

PART 3 - EXECUTION

3.1 INSTALLATION OF RACEWAYS AND BOXES

A. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for raceway selection and installation requirements for boxes, conduits, and wireways as supplemented or modified in this Section.

1. Outlet boxes shall be no smaller than 2 inches wide, 3 inches high, and 2-1/2 inches deep.

B. Comply with TIA-569-C for pull-box sizing and length of conduit and number of bends between pull points.

C. Install manufactured conduit sweeps and long-radius elbows if possible.

3.2 INSTALLATION OF CONDUCTORS AND CABLES

A. Comply with NECA 1.

B. General Requirements for Cabling:

1. Comply with TIA-568-C Series of standards.

2. Terminate all conductors and optical fibers; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, and cross-connect and patch panels.
3. Cables may not be spliced.
4. Secure and support cables at intervals not exceeding 30 inches and not more than 6 inches from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
5. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii.
6. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
7. Cold-Weather Installation: Bring cable to room temperature before dereeling. Do not use heat lamps for heating.
8. Support: Do not allow cables to lay on removable ceiling tiles.
9. Secure: Fasten securely in place with hardware specifically designed and installed so as to not damage cables.

C. Installation of Control-Circuit Conductors:

1. Install wiring in raceways. Comply with requirements specified in Section 260533 "Raceways and Boxes for Electrical Systems."

D. Low-Voltage Control Cable Installation:

1. Install cable in conduit or surface mounted raceway unless concealed above lay-in ceiling in which case Contractor shall install in free air.
2. Install cabling with horizontal and vertical cable guides.
3. Suspend copper cable not in a wireway or pathway a minimum of 8 inches above ceilings by cable supports not more than 30 inches apart.
4. Cable shall not be run through or on structural members or in contact with pipes, ducts, or other potentially damaging items. Do not run cables between structural members and corrugated panels.

3.3 REMOVAL OF CONDUCTORS AND CABLES

A. Remove abandoned conductors and cables. Abandoned conductors and cables are those installed that are not terminated at equipment and are not identified with a tag for future use.

3.4 CONTROL-CIRCUIT CONDUCTORS

A. Minimum Conductor Sizes:

1. Class 1 remote-control and signal circuits; No 14 AWG.
2. Class 2 low-energy, remote-control, and signal circuits; No. 16 AWG.
3. Class 3 low-energy, remote-control, alarm, and signal circuits; No 12 AWG.

3.5 FIRESTOPPING

A. Comply with requirements in Section 078413 "Penetration Firestopping."

3.6 GROUNDING

A. For low-voltage control wiring and cabling, comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 IDENTIFICATION

A. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.8 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:

1. Visually inspect cable jacket materials for UL or third-party certification markings.
2. Visually inspect cable placement, cable termination, grounding and bonding and labeling of all components.
3. Test cabling for shorts, opens and intermittent faults.

C. End-to-end cabling will be considered defective if it does not pass tests and inspections.

END OF SECTION

SECTION 26 0526

GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes grounding and bonding systems and equipment.

B. Section includes grounding and bonding systems and equipment, plus the following special applications:

1. Underground distribution grounding.
2. Ground bonding common with lightning protection system.
3. Foundation steel electrodes.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

1.4 INFORMATIONAL SUBMITTALS

A. As-Built Data: Plans showing dimensioned as-built locations of grounding features specified in "Field Quality Control" Article, including the following:

1. Ground rods.
2. Ground rings.
3. Grounding arrangements and connections for separately derived systems.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Comply with UL 467 for grounding and bonding materials and equipment.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Burndy; Part of Hubbell Electrical Systems.
2. Dossert; AFL Telecommunications LLC.
3. ERICO International Corporation.
4. Fushi Copperweld Inc.
5. Galvan Industries, Inc.; Electrical Products Division, LLC.
6. Harger Lightning & Grounding.
7. ILSCO.
8. O-Z/Gedney; a brand of Emerson Industrial Automation.
9. Robbins Lightning, Inc.
10. Siemens Power Transmission & Distribution, Inc.

2.2 SYSTEM DESCRIPTION

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Comply with UL 467 for grounding and bonding materials and equipment.

2.3 CONDUCTORS

A. Insulated Conductors: Copper or tinned-copper wire or cable insulated for 600 V unless otherwise required by applicable Code or authorities having jurisdiction.

B. Bare Copper Conductors:

1. Solid Conductors: ASTM B 3.
2. Stranded Conductors: ASTM B 8.
3. Tinned Conductors: ASTM B 33.
4. Bonding Cable: 28 kcmil, 14 strands of No. 17 AWG conductor, 1/4 inch in diameter.
5. Bonding Conductor: No. 4 or No. 6 AWG, stranded conductor.
6. Bonding Jumper: Copper tape, braided conductors terminated with copper ferrules; 1-5/8 inches wide and 1/16 inch thick.
7. Tinned Bonding Jumper: Tinned-copper tape, braided conductors terminated with copper ferrules; 1-5/8 inches wide and 1/16 inch thick.

C. Grounding Bus: Predrilled rectangular bars of annealed copper, 1/4 by 4 inches in cross section, with 9/32-inch holes spaced 1-1/8 inches apart. Stand-off insulators for mounting shall comply with UL 891 for use in switchboards, 600 V and shall be Lexan or PVC, impulse tested at 5000 V.

2.4 CONNECTORS

A. Listed and labeled by an NRTL acceptable to authorities having jurisdiction for applications in which used and for specific types, sizes, and combinations of conductors and other items connected.

B. Bolted Connections for Conductors and Pipes: Copper or copper alloy, pressure-type with at least two bolts.

1. Pipe Connectors: Clamp type, sized for pipe.

C. Welded Connectors: Exothermic-welding kits of types recommended by kit manufacturer for materials being joined and installation conditions.

D. Bus-Bar Connectors: Mechanical type, cast silicon bronze, solderless compression-type wire terminals, and long-barrel, two-bolt connection to ground bus bar.

2.5 GROUNDING ELECTRODES

A. Ground Rods: Copper-clad steel; 3/4 inch by 10 feet.

PART 3 - EXECUTION

3.1 APPLICATIONS

A. Conductors: Install solid conductor for No. 8 AWG and smaller, and stranded conductors for No. 6 AWG and larger unless otherwise indicated.

B. Underground Grounding Conductors: Install barecopper conductor, No. 2/0 AWG minimum.

1. Bury at least 24 inches below grade.

C. Isolated Grounding Conductors: Green-colored insulation with continuous yellow stripe. On feeders with isolated ground, identify grounding conductor where visible to normal inspection, with alternating bands of green and yellow tape, with at least three bands of green and two bands of yellow.

D. Conductor Terminations and Connections:

1. Pipe and Equipment Grounding Conductor Terminations: Bolted connectors.
2. Underground Connections: Welded connectors except at test wells and as otherwise indicated.
3. Connections to Ground Rods at Test Wells: Bolted connectors.
4. Connections to Structural Steel: Welded connectors.

3.2 GROUNDING AT THE SERVICE

A. Equipment grounding conductors and grounding electrode conductors shall be connected to the ground bus in main distribution panel. Install a main bonding jumper between the neutral and ground buses.

3.3 GROUNDING UNDERGROUND DISTRIBUTION SYSTEM COMPONENTS

A. Comply with IEEE C2 grounding requirements.

B. Pad-Mounted Transformers: Install two ground rods and ground ring around the pad. Ground pad-mounted equipment and noncurrent-carrying metal items by connecting them to underground cable and grounding electrodes. Install tinned-copper conductor not less than No. 2 AWG for ground ring and for taps to equipment grounding terminals. Bury ground ring not less than 6 inches from the foundation.

3.4 EQUIPMENT GROUNDING

A. Install insulated equipment grounding conductors with all feeders and branch circuits. Separate grounding conductors are not shown on the drawings but shall be included in all raceways as set forth on the drawings.

3.5 INSTALLATION

A. Grounding Conductors: Route along shortest and straightest paths possible unless otherwise indicated or required by Code. Avoid obstructing access or placing conductors where they may be subjected to strain, impact, or damage.

B. Ground Rods: Drive rods until tops are 2 inches below finished floor or final grade unless otherwise indicated.

1. Interconnect ground rods with grounding electrode conductor below grade and as otherwise indicated. Make connections without exposing steel or damaging coating if any.
2. For grounding electrode system, install at least three rods spaced at least one-rod length from each other and located at least the same distance from other grounding electrodes, and connect to the service grounding electrode conductor.

C. Bonding Straps and Jumpers: Install in locations accessible for inspection and maintenance except where routed through short lengths of conduit.

1. Bonding to Structure: Bond straps directly to basic structure, taking care not to penetrate any adjacent parts.
2. Bonding to Equipment Mounted on Vibration Isolation Hangers and Supports: Install bonding so vibration is not transmitted to rigidly mounted equipment.
3. Use exothermic-welded connectors for outdoor locations; if a disconnect-type connection is required, use a bolted clamp.

3.6 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. After installing grounding system but before permanent electrical circuits have been energized, test for compliance with requirements.
2. Inspect physical and mechanical condition. Verify tightness of accessible, bolted, electrical connections with a calibrated torque wrench according to manufacturer's written instructions.
3. Prepare dimensioned Drawings locating each test well, ground rod and ground-rod assembly, and other grounding electrodes. Identify each by letter in alphabetical order, and key to the record of tests and observations. Include the number of rods driven and their depth at each location, and include observations of weather and other phenomena that may affect test results. Describe measures taken to improve test results.

C. Grounding system will be considered defective if it does not pass tests and inspections.

END OF SECTION

SECTION 26 0529

HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Hangers and supports for electrical equipment and systems.
2. Construction requirements for concrete bases.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for the following:

    a. Hangers.
    b. Steel slotted support systems.
    c. Trapeze hangers.

2. Include rated capacities and furnished specialties and accessories.

B. Shop Drawings: For fabrication and installation details for electrical hangers and support systems.

1. Trapeze hangers. Include product data for components.
2. Steel slotted-channel systems.
3. Equipment supports.

PART 2 - PRODUCTS

2.1 SUPPORT, ANCHORAGE, AND ATTACHMENT COMPONENTS

A. Steel Slotted Support Systems: Comply with MFMA-4 factory-fabricated components for field assembly.

1. <u>Manufacturers:</u> Subject to compliance with requirements, provide products by one of the following:

    a. <u>Allied Tube & Conduit; a part of Atkore International</u>.

b. Cooper B-Line, Inc.; a division of Cooper Industries.
c. ERICO International Corporation.
d. Flex-Strut Inc.
e. GS Metals Corp.
f. G-Strut.
g. Haydon Corporation.
h. Metal Ties Innovation.
i. Thomas & Betts Corporation, A Member of the ABB Group.
j. Unistrut; an Atkore International company.

2. Material: Galvanized steel.
3. Channel Width: 1-5/8 inches.
4. Metallic Coatings: Hot-dip galvanized after fabrication and applied according to MFMA-4.
5. Protect finishes on exposed surfaces from damage by applying a strippable, temporary protective covering before shipping.
6. Channel Dimensions: Selected for applicable load criteria.

B. Conduit and Cable Support Devices: Steel hangers, clamps, and associated fittings, designed for types and sizes of raceway or cable to be supported.

C. Support for Conductors in Vertical Conduit: Factory-fabricated assembly consisting of threaded body and insulating wedging plug or plugs for nonarmored electrical conductors or cables in riser conduits. Plugs shall have number, size, and shape of conductor gripping pieces as required to suit individual conductors or cables supported. Body shall be made of malleable iron.

D. Structural Steel for Fabricated Supports and Restraints: ASTM A 36/A 36M steel plates, shapes, and bars; black and galvanized.

E. Mounting, Anchoring, and Attachment Components: Items for fastening electrical items or their supports to building surfaces include the following:

1. Powder-Actuated Fasteners: Anchors using explosive charges to drive inserts into concrete shall not be used.
2. Mechanical-Expansion Anchors: Insert-wedge-type, zinc-coated steel, for use in hardened portland cement concrete, with tension, shear, and pullout capacities appropriate for supported loads and building materials where used.

a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1) Cooper B-Line, Inc.; a division of Cooper Industries.
2) Empire Tool and Manufacturing Co., Inc.
3) Hilti, Inc.
4) ITW Ramset/Red Head; Illinois Tool Works, Inc.

3. Concrete Inserts: Steel or malleable-iron, slotted support system units are similar to MSS Type 18 units and comply with MFMA-4 or MSS SP-58.

4. Clamps for Attachment to Steel Structural Elements: MSS SP-58 units are suitable for attached structural element.
5. Through Bolts: Structural type, hex head, and high strength. Comply with ASTM A 325.
6. Toggle Bolts: All-steel springhead type.
7. Hanger Rods: Threaded steel.

2.2 FABRICATED METAL EQUIPMENT SUPPORT ASSEMBLIES

A. Description: Welded or bolted structural-steel shapes, shop or field fabricated to fit dimensions of supported equipment.

B. Materials: Comply with requirements in Section 055000 "Metal Fabrications" for steel shapes and plates.

PART 3 - EXECUTION

3.1 APPLICATION

A. Comply with NECA 1 and NECA 101 for application of hangers and supports for electrical equipment and systems unless requirements in this Section are stricter.

B. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."

C. Maximum Support Spacing and Minimum Hanger Rod Size for Raceway: Space supports for EMTs, IMCs, and RMCs as required by NFPA 70. Minimum rod size shall be 1/4 inch in diameter.

D. Multiple Raceways or Cables: Install trapeze-type supports fabricated with steel slotted support system, sized so capacity can be increased by at least 25 percent in future without exceeding specified design load limits.

1. Secure raceways and cables to these supports with two-bolt conduit clamps.

3.2 SUPPORT INSTALLATION

A. Comply with NECA 1 and NECA 101 for installation requirements except as specified in this article.

B. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb.

C. Mounting and Anchorage of Surface-Mounted Equipment and Components: Anchor and fasten electrical items and their supports to building structural elements by the following methods unless otherwise indicated by code:

1. To Wood: Fasten with lag screws or through bolts.
2. To New Concrete: Bolt to concrete inserts.
3. To Masonry: Approved toggle-type bolts on hollow masonry units and expansion anchor fasteners on solid masonry units.
4. To Existing Concrete: Expansion anchor fasteners. Anchors using explosive charges to drive inserts into concrete shall not be used.
5. To Steel: Beam clamps (MSS SP-58, Type 19, 21, 23, 25, or 27), complying with MSS SP-69 or metal framing channel welded to structure.
6. To Light Steel: Sheet metal screws.

7. Items Mounted on Hollow Walls and Nonstructural Building Surfaces: Mount cabinets, panelboards, disconnect switches, control enclosures, pull and junction boxes, transformers, and other devices on slotted-channel racks attached to substrate.

D. Drill holes for expansion anchors in concrete at locations and to depths that avoid the need for reinforcing bars.

E. Repair fireproofing damaged as a result of installing clamps or supports to structural steel.

3.3 INSTALLATION OF FABRICATED METAL SUPPORTS

A. Comply with installation requirements in Section 055000 "Metal Fabrications" for site-fabricated metal supports.

B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor electrical materials and equipment.

C. Field Welding: Comply with AWS D1.1/D1.1M.

3.4 CONCRETE BASES

A. Construct concrete bases of dimensions indicated but not less than 4 inches larger in both directions than supported unit, and so anchors will be a minimum of 10 bolt diameters from edge of the base.

B. Concrete bases to be 4” minimum thick unless otherwise called for on the drawings.

C. Use 3000-psi, 28-day compressive-strength concrete. Concrete materials, reinforcement, and placement requirements are specified in Section 033000 "Cast-in-Place Concrete."

D. Rough up floor to assure bonding of base to floor. Anchor the base to the floor with reinforcing bars set in the floor or power driven studs. Provide two layers 6 x 6 #6 welded wire reinforcing mesh in base.

E. Anchor equipment to concrete base as follows:

1. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
2. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

F. Provide concrete bases for the following floor mounted equipment:

1. Transformers.

3.5 PAINTING

A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

1. Apply paint by brush or spray to provide minimum dry film thickness of 2.0 mils.

B. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

C. Prime paint all structural steel installed for pipe or equipment supports or burned by welding with one coat of rust inhibitive black paint at the time of installation.

END OF SECTION

SECTION 26 0533

RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Metal conduits, tubing, and fittings.
2. Nonmetal conduits, tubing, and fittings.
3. Surface raceways.
4. Boxes, enclosures, and cabinets.

B. Related Requirements:

1. Section 260543 "Underground Ducts and Raceways for Electrical Systems" for exterior ductbanks, manholes, and underground utility construction.
2. Section 270528 "Pathways for Communications Systems" for conduits, wireways, surface pathways, innerduct, boxes, faceplate adapters, enclosures, cabinets, and handholes serving communications systems.
3. Section 280528 "Pathways for Electronic Safety and Security" for conduits, surface pathways, innerduct, boxes, and faceplate adapters serving electronic safety and security.

1.3 DEFINITIONS

A. ARC: Aluminum rigid conduit.

B. GRC: Galvanized rigid steel conduit.

C. IMC: Intermediate metal conduit.

1.4 ACTION SUBMITTALS

A. Product Data: For surface raceways, wireways and fittings, floor boxes, hinged-cover enclosures, and cabinets.

PART 2 - PRODUCTS

2.1 METAL CONDUITS, TUBING, AND FITTINGS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. AFC Cable Systems, Inc.
2. Allied Tube & Conduit; a part of Atkore International.
3. Anamet Electrical, Inc.
4. Electri-Flex Company.
5. FSR Inc.
6. O-Z/Gedney; a brand of Emerson Industrial Automation.
7. Patriot Aluminum Products, LLC.
8. Picoma Industries, Inc.
9. Republic Conduit.
10. Robroy Industries.
11. Southwire Company.
12. Thomas & Betts Corporation, A Member of the ABB Group.
13. Western Tube and Conduit Corporation.

B. Listing and Labeling: Metal conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. GRC: Comply with ANSI C80.1 and UL 6.

D. IMC: Comply with ANSI C80.6 and UL 1242.

E. EMT: Comply with ANSI C80.3 and UL 797.

F. FMC: Comply with UL 1; zinc-coated steel.

G. LFMC: Flexible steel conduit with PVC jacket and complying with UL 360.

H. Fittings for Metal Conduit: Comply with NEMA FB 1 and UL 514B.

1. Conduit Fittings for Hazardous (Classified) Locations: Comply with UL 886 and NFPA 70.
2. Fittings for EMT:
   a. Material: Steel.
   b. Type: Compression.
3. Expansion Fittings: PVC or steel to match conduit type, complying with UL 651, rated for environmental conditions where installed, and including flexible external bonding jumper.

I. Joint Compound for IMC, GRC, or ARC: Approved, as defined in NFPA 70, by authorities having jurisdiction for use in conduit assemblies, and compounded for use to lubricate and protect threaded conduit joints from corrosion and to enhance their conductivity.

2.2 SURFACE RACEWAYS

A. Listing and Labeling: Surface raceways and tele-power poles shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Surface Metal Raceways: Galvanized steel with snap-on covers complying with UL 5. Finish: Primed ready for painting.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Hubbell Incorporated; Wiring Device-Kellems.
    b. MonoSystems, Inc.
    c. Panduit Corp.
    d. Wiremold.

2.3 BOXES, ENCLOSURES, AND CABINETS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Adalet.
2. Cooper Technologies Company.
3. EGS/Appleton Electric.
4. Erickson Electrical Equipment Company.
5. FSR Inc.
6. Hoffman; a brand of Pentair Equipment Protection.
7. Hubbell Incorporated.
8. Kraloy.
9. Milbank Manufacturing Co.
10. MonoSystems, Inc.
11. Oldcastle Enclosure Solutions.
12. O-Z/Gedney; a brand of Emerson Industrial Automation.
13. RACO; Hubbell.
14. Robroy Industries.
15. Spring City Electrical Manufacturing Company.
16. Stahlin Non-Metallic Enclosures.
17. Thomas & Betts Corporation, A Member of the ABB Group.

B. General Requirements for Boxes, Enclosures, and Cabinets: Boxes, enclosures, and cabinets installed in wet locations shall be listed for use in wet locations.

C. Sheet Metal Outlet and Device Boxes: Comply with NEMA OS 1 and UL 514A.

D. Metal Floor Boxes:

1. Material: Cast metal.
2. Type: Fully adjustable.
3. Shape: Rectangular.
4. Listing and Labeling: Metal floor boxes shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

E. Nonmetallic Floor Boxes: Nonadjustable, round.

1. Listing and Labeling: Nonmetallic floor boxes shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

F. Luminaire Outlet Boxes: Nonadjustable, designed for attachment of luminaire weighing 50 lb. Outlet boxes designed for attachment of luminaires weighing more than 50 lb shall be listed and marked for the maximum allowable weight.

G. Paddle Fan Outlet Boxes: Nonadjustable, designed for attachment of paddle fan weighing 70 lb.

1. Listing and Labeling: Paddle fan outlet boxes shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

H. Small Sheet Metal Pull and Junction Boxes: NEMA OS 1.

I. Box extensions used to accommodate new building finishes shall be of same material as recessed box.

J. Device Box Dimensions: 4 inches square by 2-1/8 inches deep.

K. Gangable boxes are prohibited.

L. Hinged-Cover Enclosures: Comply with UL 50 and NEMA 250, Type 1 with continuous-hinge cover with flush latch unless otherwise indicated.

1. Metal Enclosures: Steel, finished inside and out with manufacturer's standard enamel.
2. Nonmetallic Enclosures: Plastic.
3. Interior Panels: Steel; all sides finished with manufacturer's standard enamel.

M. Cabinets:

1. NEMA 250, Type 1 galvanized-steel box with removable interior panel and removable front, finished inside and out with manufacturer's standard enamel.
2. Hinged door in front cover with flush latch and concealed hinge.
3. Key latch to match panelboards.
4. Metal barriers to separate wiring of different systems and voltage.
5. Accessory feet where required for freestanding equipment.
6. Nonmetallic cabinets shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

PART 3 - EXECUTION

3.1 RACEWAY APPLICATION

A. Outdoors: Apply raceway products as specified below unless otherwise indicated:

1. Exposed Conduit: GRC.
2. Concealed Conduit, Aboveground: GRC.
3. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): LFMC.

4. Boxes and Enclosures, Aboveground: NEMA 250, Type 3R.

B. Indoors: Apply raceway products as specified below unless otherwise indicated:

1. Exposed, Not Subject to Physical Damage: EMT.
2. Exposed, Not Subject to Severe Physical Damage: EMT.
3. Concealed in Ceilings and Interior Walls and Partitions: EMT.
4. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): LFMC.
5. Damp or Wet Locations: GRC.
6. Boxes and Enclosures: NEMA 250, Type 1, except use NEMA 250, Type 4 stainless steel in institutional and commercial kitchens and damp or wet locations.

a. All boxes installed in poured concrete, block, brick or tile shall be masonry type.
b. All multiple gang switch boxes shall be solid gang box.
c. All surface-mounted boxes shall be cast FS or FD type.
d. The minimum size of boxes shall be 4” x 4” x 2-1/8” minimum depth. For single device installation, install square cut single device cover.
e. Install all device boxes with square cut device covers for number of devices required.
f. For multiple gang boxes installed for more than one 277 volt switch, a barrier shall be installed between each box gang.

C. Minimum Raceway Size: 3/4-inch trade size.

D. Raceway Fittings: Compatible with raceways and suitable for use and location.

1. Rigid and Intermediate Steel Conduit: Use threaded rigid steel conduit fittings unless otherwise indicated. Comply with NEMA FB 2.10.
2. EMT: Use compression, steel fittings. Comply with NEMA FB 2.10.
3. Flexible Conduit: Use only fittings listed for use with flexible conduit. Comply with NEMA FB 2.20.

E. Install surface raceways only where indicated on Drawings.

F. Do not install nonmetallic conduit where ambient temperature exceeds 120 deg F.

3.2 INSTALLATION

A. Comply with NECA 1 and NECA 101 for installation requirements except where requirements on Drawings or in this article are stricter. Comply with NECA 102 for aluminum conduits. Comply with NFPA 70 limitations for types of raceways allowed in specific occupancies and number of floors.

B. Keep raceways at least 6 inches away from parallel runs of flues and steam or hot-water pipes. Install horizontal raceway runs above water and steam piping.

C. Complete raceway installation before starting conductor installation.

D. Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems" for hangers and supports.

E. Conduits and raceways shall not be supported from plumbing lines, ductwork or supports for equipment provided by other trades.

F. Arrange stub-ups so curved portions of bends are not visible above finished slab.

G. Install no more than the equivalent of three 90-degree bends in any conduit run except for control wiring conduits, for which fewer bends are allowed. Support within 12 inches of changes in direction.

H. Conceal conduit and EMT within finished walls, ceilings, and floors unless otherwise indicated. Install conduits parallel or perpendicular to building lines. In mechanical equipment rooms conduit and EMT may be exposed at the ceiling or on the walls.

I. Support conduit within 12 inches of enclosures to which attached.

J. Raceways Embedded in Slabs:

1. There shall not be any raceways installed horizontally in concrete slabs throughout the building, except where specifically noted and detailed on the drawings.

K. Stub-ups to Above Recessed Ceilings:

1. Use EMT, IMC, or RMC for raceways.
2. Use a conduit bushing or insulated fitting to terminate stub-ups not terminated in hubs or in an enclosure.

L. Threaded Conduit Joints, Exposed to Wet, Damp, Corrosive, or Outdoor Conditions: Apply listed compound to threads of raceway and fittings before making up joints. Follow compound manufacturer's written instructions.

M. Coat field-cut threads on PVC-coated raceway with a corrosion-preventing conductive compound prior to assembly.

N. Raceway Terminations at Locations Subject to Moisture or Vibration: Use insulating bushings to protect conductors including conductors smaller than No. 4 AWG.

O. Terminate threaded conduits into threaded hubs or with locknuts on inside and outside of boxes or cabinets. Install bushings on conduits up to 1-1/4-inch trade size and insulated throat metal bushings on 1-1/2-inch trade size and larger conduits terminated with locknuts. Install insulated throat metal grounding bushings on service conduits.

P. Install raceways square to the enclosure and terminate at enclosures with locknuts. Install locknuts hand tight plus 1/4 turn more.

Q. Do not rely on locknuts to penetrate nonconductive coatings on enclosures. Remove coatings in the locknut area prior to assembling conduit to enclosure to assure a continuous ground path.

R. Cut conduit perpendicular to the length. For conduits 2-inch trade size and larger, use roll cutter or a guide to make cut straight and perpendicular to the length.

S. Install pull wires in empty raceways. Use polypropylene or monofilament plastic line with not less than 200-lb tensile strength. Leave at least 12 inches of slack at each end of pull wire. Cap underground raceways designated as spare above grade alongside raceways in use.

T. Surface Raceways:

1. Install surface raceway with a minimum 2-inchradius control at bend points.

2. Secure surface raceway with screws or other anchor-type devices at intervals not exceeding 48 inches and with no less than two supports per straight raceway section. Support surface raceway according to manufacturer's written instructions. Tape and glue are not acceptable support methods.

U. Install raceway sealing fittings at accessible locations according to NFPA 70 and fill them with listed sealing compound. For concealed raceways, install each fitting in a flush steel box with a blank cover plate having a finish similar to that of adjacent plates or surfaces. Install raceway sealing fittings according to NFPA 70.

V. Install devices to seal raceway interiors at accessible locations. Locate seals so no fittings or boxes are between the seal and the following changes of environments. Seal the interior of all raceways at the following points:

1. Where conduits pass from warm to cold locations, such as boundaries of refrigerated spaces.
2. Where an underground service raceway enters a building or structure.
3. Where otherwise required by NFPA 70.

W. Comply with manufacturer's written instructions for solvent welding RNC and fittings.

X. Expansion-Joint Fittings:

1. Install in each run of aboveground RNC that is located where environmental temperature change may exceed 30 deg F and that has straight-run length that exceeds 25 feet. Install in each run of aboveground RMC and EMT conduit that is located where environmental temperature change may exceed 100 deg F and that has straight-run length that exceeds 100 feet.
2. Install type and quantity of fittings that accommodate temperature change listed for each of the following locations:

   a. Outdoor Locations Not Exposed to Direct Sunlight: 125 deg F temperature change.
   b. Outdoor Locations Exposed to Direct Sunlight: 155 deg F temperature change.
   c. Indoor Spaces Connected with Outdoors without Physical Separation: 125 deg F temperature change.
   d. Attics: 135 deg F temperature change.

3. Install fitting(s) that provide expansion and contraction for at least 0.00041 inch per foot of length of straight run per deg F of temperature change for PVC conduits. Install fitting(s) that provide expansion and contraction for at least 0.000078 inch per foot of length of straight run per deg F of temperature change for metal conduits.
4. Install expansion fittings at all locations where conduits cross building or structure expansion joints.
5. Install each expansion-joint fitting with position, mounting, and piston setting selected according to manufacturer's written instructions for conditions at specific location at time of installation. Install conduit supports to allow for expansion movement.

Y. Flexible Conduit Connections: Comply with NEMA RV 3. Use a maximum of 72 inches of flexible conduit for recessed and semirecessed luminaires, equipment subject to vibration, noise transmission, or movement; and for transformers and motors.

1. Use LFMC in damp or wet locations subject to severe physical damage.
2. Use LFMC or LFNC in damp or wet locations not subject to severe physical damage.

Z. Mount boxes at heights indicated on Drawings. If mounting heights of boxes are not individually indicated, give priority to ADA requirements. Install boxes with height measured to center of box unless otherwise indicated.

AA. Recessed Boxes in Masonry Walls: Saw-cut opening for box in center of cell of masonry block, and install box flush with surface of wall. Prepare block surfaces to provide a flat surface for a raintight connection between box and cover plate or supported equipment and box.

BB. Horizontally separate boxes mounted on opposite sides of walls so they are not in the same vertical channel.

CC. Locate boxes so that cover or plate will not span different building finishes.

DD. Support boxes of three gangs or more from more than one side by spanning two framing members or mounting on brackets specifically designed for the purpose.

EE. Fasten junction and pull boxes to or support from building structure. Do not support boxes by conduits.

FF. Set metal floor boxes level and flush with finished floor surface.

GG. Set nonmetallic floor boxes level. Trim after installation to fit flush with finished floor surface.

3.3 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.4 FIRESTOPPING

A. Install firestopping at penetrations of fire-rated floor and wall assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.5 PROTECTION

A. Protect coatings, finishes, and cabinets from damage and deterioration.

1. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.
2. Repair damage to PVC coatings or paint finishes with matching touchup coating recommended by manufacturer.

B. Protect work from injury by keeping all conduit and boxes capped and plugged or otherwise protected. This includes damage by freezing and / or stoppage from building materials, sand, dirt or concrete.

END OF SECTION

SECTION 26 0543

UNDERGROUND DUCTS AND RACEWAYS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Direct-buried conduit, ducts, and duct accessories.

1.3 DEFINITIONS

A. Trafficways: Locations where vehicular or pedestrian traffic is a normal course of events.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include duct-bank materials, including separators and miscellaneous components.
2. Include ducts and conduits and their accessories, including elbows, end bells, bends, fittings, and solvent cement.
3. Include accessories for handholes.
4. Include warning tape.

1.5 FIELD CONDITIONS

A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions, and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Notify Architect and Owner no fewer than seven days in advance of proposed interruption of electrical service.
2. Do not proceed with interruption of electrical service without Architect's or Owner's written permission.

B. Ground Water: Assume ground-water level is 36 inches below ground surface unless a higher water table is noted on Drawings.

C. Location of Existing Buried Utilities: The contract documents do not claim to show all existing buried utilities on site.

1. Provide services of a private locating service to identify and locate all existing utilities that could be affected by excavation and new work.
2. Repair all damage caused by the Contractor's activities promptly to the satisfaction of the Owner of the damaged utility. All such repairs shall be conducted at the sole expense of the Contractor that damaged the utility.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR DUCTS AND RACEWAYS

A. Comply with ANSI C2.

2.2 CONDUIT

A. Rigid Steel Conduit: Galvanized. Comply with ANSI C80.1.

B. RNC: NEMA TC 2, Type EPC-40-PVC and Type EPC-80-PVC, UL 651, with matching fittings by same manufacturer as the conduit, complying with NEMA TC 3 and UL 514B.

2.3 NONMETALLIC DUCTS AND DUCT ACCESSORIES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. ARNCO Corp.
2. Beck Manufacturing.
3. CANTEX INC.
4. CertainTeed Corporation.
5. Condux International, Inc.
6. ElecSys, Inc.
7. Electri-Flex Company.
8. IPEX USA LLC.
9. Lamson & Sessions.
10. Manhattan/CDT.

B. Underground Plastic Utilities Duct: NEMA TC 2, UL 651, ASTM F 512, Type EPC-80 and Type EPC-40, with matching fittings complying with NEMA TC 3 by same manufacturer as the duct.

C. Duct Accessories:

1. Duct Separators: Factory-fabricated rigid PVC interlocking spacers, sized for type and size of ducts with which used, and selected to provide minimum duct spacing indicated while supporting ducts during concreting or backfilling.
2. Warning Tape: Underground-line warning tape specified in Section 260553 "Identification for Electrical Systems."

PART 3 - EXECUTION

3.1 PREPARATION

A. Coordinate layout and installation of ducts, manholes, handholes, and boxes with final arrangement of other utilities, site grading, and surface features as determined in the field. Notify Architect if there is a conflict between areas of excavation and existing structures or archaeological sites to remain.

B. Coordinate elevations of ducts and duct-bank entrances into manholes, handholes, and boxes with final locations and profiles of ducts and duct banks, as determined by coordination with other utilities, underground obstructions, and surface features. Revise locations and elevations as required to suit field conditions and to ensure that duct runs drain to manholes and handholes, and as approved by Architect.

C. Clear and grub vegetation to be removed, and protect vegetation to remain according to Section 311000 "Site Clearing." Remove and stockpile topsoil for reapplication according to Section 311000 "Site Clearing."

3.2 UNDERGROUND DUCT APPLICATION

A. Ducts for Electrical Feeders 600 V and Less: RNC, NEMA Type EPC-40-PVC, in direct-buried duct bank unless otherwise indicated.

B. Ducts for Electrical Branch Circuits: RNC, NEMA Type EPC-40-PVC, in direct-buried duct bank unless otherwise indicated.

3.3 EARTHWORK

A. Excavation and Backfill: Comply with Section 312000 "Earth Moving," but do not use heavy-duty, hydraulic-operated, compaction equipment.

B. Restore surface features at areas disturbed by excavation, and re-establish original grades unless otherwise indicated. Replace removed sod immediately after backfilling is completed.

C. Restore areas disturbed by trenching, storing of dirt, cable laying, and other work. Restore vegetation and include necessary topsoiling, fertilizing, liming, seeding, sodding, sprigging, and mulching. Comply with Section 329200 "Turf and Grasses" and Section 329300 "Plants."

D. Cut and patch existing pavement in the path of underground ducts and utility structures according to the "Cutting and Patching" Article in Section 017300 "Execution."

3.4 DUCT INSTALLATION

A. Install ducts according to NEMA TCB 2.

B. Slope: Pitch ducts a minimum slope of 1:300 down toward manholes and handholes and away from buildings and equipment. Slope ducts from a high point in runs between two manholes, to drain in both directions.

C. Curves and Bends: Use 5-degree angle couplings for small changes in direction. Use manufactured long sweep bends with a minimum radius of 48 inches, both horizontally and vertically, at other locations unless otherwise indicated.

D. Joints: Use solvent-cemented joints in ducts and fittings and make watertight according to manufacturer's written instructions. Stagger couplings so those of adjacent ducts do not lie in same plane.

E. Duct Entrances to Concrete and Polymer Concrete Handholes: Use end bells, spaced approximately 10 inches o.c. for 5-inch ducts, and vary proportionately for other duct sizes.

1. Begin change from regular spacing to end-bell spacing 10 feet from the end bell without reducing duct line slope and without forming a trap in the line.
2. Direct-Buried Duct Banks: Install an expansion and deflection fitting in each conduit in the area of disturbed earth adjacent to manhole or handhole. Install an expansion fitting near the center of all straight line direct-buried duct banks with calculated expansion of more than 3/4 inch.
3. Grout end bells into structure walls from both sides to provide watertight entrances.

F. Building Wall Penetrations: Make a transition from underground duct to rigid steel conduit at least 10 feet outside the building wall, without reducing duct line slope away from the building, and without forming a trap in the line. Use fittings manufactured for duct-to-conduit transition. Install conduit penetrations of building walls as specified in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

G. Sealing: Provide temporary closure at terminations of ducts that have cables pulled. Seal spare ducts at terminations. Use sealing compound and plugs to withstand at least 15-psig hydrostatic pressure.

H. Pulling Cord: Install 100-lbf-test nylon cord in empty ducts.

I. Direct-Buried Duct Banks:

1. Excavate trench bottom to provide firm and uniform support for duct bank. Comply with requirements in Section 312000 "Earth Moving" for preparation of trench bottoms for pipes less than 6 inches in nominal diameter.
2. Support ducts on duct separators coordinated with duct size, duct spacing, and outdoor temperature.
3. Space separators close enough to prevent sagging and deforming of ducts, with not less than four spacers per 20 feet of duct. Secure separators to earth and to ducts to prevent displacement during backfill and yet permit linear duct movement due to expansion and contraction as temperature changes. Stagger spacers approximately 6 inches between tiers.
4. Depth: Install top of duct bank at least 36 inches below finished grade unless otherwise indicated.
5. Set elevation of bottom of duct bank below frost line.
6. Install ducts with a minimum of 3 inches between ducts for like services and 6 inches between power and signal ducts.
7. Elbows: Install manufactured duct elbows for stub-ups at poles and equipment, at building entrances through floor, and at changes of direction in duct run unless otherwise indicated. Encase elbows for stub-up ducts throughout length of elbow.
8. Install manufactured rigid steel conduit elbows for stub-ups at poles and equipment, at building entrances through floor, and at changes of direction in duct run.

a. Couple steel conduits to ducts with adapters designed for this purpose, and encase coupling with 3 inches of concrete.

b. For equipment mounted on outdoor concrete bases, extend steel conduit horizontally a minimum of 60 inches from edge of equipment pad or foundation. Install insulated grounding bushings on terminations at equipment.

9. After installing first tier of ducts, backfill and compact. Start at tie-in point and work toward end of duct run, leaving ducts at end of run free to move with expansion and contraction as temperature changes during this process. Repeat procedure after placing each tier. After placing last tier, hand place backfill to 4 inches over ducts and hand tamp. Firmly tamp backfill around ducts to provide maximum supporting strength. Use hand tamper only. After placing controlled backfill over final tier, make final duct connections at end of run and complete backfilling with normal compaction. Comply with requirements in Section 312000 "Earth Moving" for installation of backfill materials.

a. Place minimum 3 inches of sand as a bed for duct bank. Place sand to a minimum of 6 inches above top level of duct bank.

b. Place minimum 6 inches of engineered fill above concrete encasement of duct bank.

J. Warning Tape: Bury warning tape approximately 12 inches above all concrete-encased ducts and duct banks. Align tape parallel to and within 3 inches of centerline of duct bank. Provide an additional warning tape for each 12-inch increment of duct-bank width over a nominal 18 inches. Space additional tapes 12 inches apart, horizontally.

3.5 GROUNDING

A. Ground underground ducts and utility structures according to Section 260526 "Grounding and Bonding for Electrical Systems."

3.6 CLEANING

A. Pull leather-washer-type duct cleaner, with graduated washer sizes, through full length of ducts. Follow with rubber duct swab for final cleaning and to assist in spreading lubricant throughout ducts.

B. Clean internal surfaces of manholes, including sump. Remove foreign material.

END OF SECTION

SECTION 26 0544

SLEEVES AND SLEEVE SEALS FOR ELECTRICAL RACEWAYS AND CABLING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Sleeves for raceway and cable penetration of non-fire-rated construction walls and floors.
2. Grout.
3. Silicone sealants.

B. Related Requirements:

1. Section 078413 "Penetration Firestopping" for penetration firestopping installed in fire-resistance-rated walls, horizontal assemblies, and smoke barriers, with and without penetrating items.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 SLEEVES

A. Wall Sleeves:

1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

B. PVC-Pipe Sleeves: ASTM D 1785, Schedule 40.

2.2 GROUT

A. Description: Nonshrink; recommended for interior and exterior sealing openings in non-fire-rated walls or floors.

B. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.

C. Design Mix: 5000-psi, 28-day compressive strength.

D. Packaging: Premixed and factory packaged.

2.3 SILICONE SEALANTS

A. Silicone Sealants: Single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below.

1. Grade: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces that are not fire rated.

B. Silicone Foams: Multicomponent, silicone-based liquid elastomers that, when mixed, expand and cure in place to produce a flexible, nonshrinking foam.

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION FOR NON-FIRE-RATED ELECTRICAL PENETRATIONS

A. Comply with NECA 1.

B. Comply with NEMA VE 2 for cable tray and cable penetrations.

C. Sleeves for Conduits Penetrating Above-Grade Non-Fire-Rated Concrete and Masonry-Unit Floors and Walls:

1. Interior Penetrations of Non-Fire-Rated Walls and Floors:

a. Seal annular space between sleeve and raceway or cable, using joint sealant appropriate for size, depth, and location of joint. Comply with requirements in Section 079200 "Joint Sealants."
b. Seal space outside of sleeves with mortar or grout. Pack sealing material solidly between sleeve and wall so no voids remain. Tool exposed surfaces smooth; protect material while curing.

2. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
3. Size pipe sleeves to provide 1/4-inch annular clear space between sleeve and raceway or cable unless sleeve seal is to be installed.
4. Install sleeves for wall penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of walls. Cut sleeves to length for mounting flush with both surfaces of walls. Deburr after cutting.
5. Install sleeves for floor penetrations. Extend sleeves installed in floors 2 inches above finished floor level. Install sleeves during erection of floors.

D. Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies:

1. Use circular metal sleeves unless penetration arrangement requires rectangular sleeved opening.

2. Seal space outside of sleeves with approved joint compound for gypsum board assemblies.

E. Roof-Penetration Sleeves: Seal penetration of individual raceways and cables with flexible boot-type flashing units applied in coordination with roofing work.

F. Aboveground, Exterior-Wall Penetrations: Seal penetrations using steel pipe sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.

G. Underground, Exterior-Wall and Floor Penetrations: Install cast-iron pipe sleeves. Size sleeves to allow for 1-inch annular clear space between raceway or cable and sleeve for installing sleeve-seal system.

END OF SECTION

SECTION 26 0553

IDENTIFICATION FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Identification for conductors.
2. Underground-line warning tape.
3. Equipment identification labels, including arc-flash warning labels.
4. Miscellaneous identification products.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Comply with ASME A13.1.

B. Comply with NFPA 70.

C. Comply with 29 CFR 1910.144 and 29 CFR 1910.145.

D. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes.

1. Temperature Change: 120 deg F, ambient; 180 deg F, material surfaces.

2.2 TAPES AND STENCILS:

A. Underground-Line Warning Tape

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Brady Corporation.
   b. Ideal Industries, Inc.
   c. LEM Products Inc.
   d. Marking Services, Inc.
   e. Reef Industries, Inc.

2. Tape:

a. Recommended by manufacturer for the method of installation and suitable to identify and locate underground electrical and communications utility lines.
b. Printing on tape shall be permanent and shall not be damaged by burial operations.
c. Tape material and ink shall be chemically inert and not subject to degradation when exposed to acids, alkalis, and other destructive substances commonly found in soils.

3. Color and Printing:

a. Comply with ANSI Z535.1, ANSI Z535.2, ANSI Z535.3, ANSI Z535.4, and ANSI Z535.5.
b. Inscriptions for Red-Colored Tapes: "ELECTRIC LINE, HIGH VOLTAGE".

4. Tape Construction:

a. Detectable three-layer laminate, consisting of a printed pigmented polyolefin film, a solid aluminum-foil core, and a clear protective film that allows inspection of the continuity of the conductive core; bright colored, continuous-printed on one side with the inscription of the utility, compounded for direct-burial service.
b. Width: 3 inches.
c. Overall Thickness: 5 mils.
d. Foil Core Thickness: 0.35 mil.
e. Tensile according to ASTM D 882: 70 lbf and 4600 psi.

2.3 SIGNS

A. Laminated Acrylic or Melamine Plastic Signs:

1. Engraved legend.
2. Thickness:

a. For signs up to 20 sq. inches, minimum 1/16-inch-.
b. For signs larger than 20 sq. inches, 1/8 inch thick.
c. Engraved legend with black letters on white face.
d. Punched or drilled for mechanical fasteners.
e. Framed with mitered acrylic molding and arranged for attachment at applicable equipment.

3. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Brady Corporation.
b. Carlton Industries, LP.
c. emedco.

2.4 MISCELLANEOUS IDENTIFICATION PRODUCTS

A. Fasteners for Labels and Signs: Self-tapping, stainless-steel screws or stainless-steel machine screws with nuts and flat and lock washers.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Verify and coordinate identification names, abbreviations, colors, and other features with requirements in other Sections requiring identification applications, Drawings, Shop Drawings, manufacturer's wiring diagrams, and operation and maintenance manual. Use consistent designations throughout Project.

B. Install identifying devices before installing acoustical ceilings and similar concealment.

C. Verify identity of each item before installing identification products.

D. Install identification materials and devices at locations for most convenient viewing without interference with operation and maintenance of equipment. Install access doors or panels to provide view of identifying devices.

E. Apply identification devices to surfaces that require finish after completing finish work.

F. Attach signs and plastic labels that are not self-adhesive type with mechanical fasteners appropriate to the location and substrate.

G. During backfilling of trenches, install continuous underground-line warning tape directly above cable or raceway at 6 to 8 inches below finished grade. Use multiple tapes where width of multiple lines installed in a common trench or concrete envelope exceeds 16 inches overall.

3.2 IDENTIFICATION SCHEDULE

A. Power-Circuit Conductor Identification, 600 V or Less: For conductors in vaults, pull and junction boxes, manholes, and handholes, use color-coding conductor tape to identify the phase.

1. Color-Coding for Phase- and Voltage-Level Identification, 600 V or Less: Use colors listed below for ungrounded service feeder and branch-circuit conductors.

    a. Color shall be factory applied or field applied for sizes larger than No. 8 AWG if authorities having jurisdiction permit.

    b. Colors for 208/120-V Circuits:

        1) Phase A: Black.
        2) Phase B: Red.
        3) Phase C: Blue.
        4) Neutral: White.
        5) Ground: Green.

    c. Field-Applied, Color-Coding Conductor Tape: Apply in half-lapped turns for a minimum distance of 6 inches from terminal points and in boxes where splices or taps are made. Apply last two turns of tape with no tension to prevent possible unwinding. Locate bands to avoid obscuring factory cable markings.

B. Locations of Underground Lines: Identify with underground-line warning tape for power, lighting, communication, and control wiring and optical-fiber cable.

1. Install underground-line warning tape for direct-buried cables and cables in raceways.

C. Arc Flash Warning Labeling: Self-adhesive thermal transfer vinyl labels.

1. Comply with NFPA 70E and ANSI Z535.4.
2. Comply with Section 260574 "Overcurrent Protective Device Arc-Flash Study" requirements for arc-flash warning labels.

D. Equipment Identification Labels: On each unit of equipment, install unique designation label that is consistent with wiring diagrams, schedules, and operation and maintenance manual. Apply labels to disconnect switches and protection equipment, central or master units, control panels, control stations, terminal cabinets, and racks of each system. Systems include power, lighting, control, communication, signal, monitoring, and alarm unless equipment is provided with its own identification.

1. Labeling Instructions:

a. Indoor Equipment: Engraved, laminated acrylic or melamine plastic label, punched or drilled for mechanical fasteners. Unless otherwise indicated, provide a single line of text with 1/2-inch-high letters on 1-1/2-inch-high label; where two lines of text are required, use labels 2 inches high.
b. Outdoor Equipment: Engraved, laminated acrylic or melamine label.
c. Elevated Components: Increase sizes of labels and letters to those appropriate for viewing from the floor.
d. Fasten labels with appropriate mechanical fasteners that do not change the NEMA or NRTL rating of the enclosure.
e. Attach labels with screws and not adhesives.

2. Equipment To Be Labeled:

a. Panelboards: Typewritten directory of circuits in the location provided by panelboard manufacturer. Panelboard identification shall be in the form of a engraved, laminated acrylic or melamine label.
b. Enclosures and electrical cabinets.
c. Transformers: Label that includes tag designation shown on Drawings for the transformer, feeder, and panelboards or equipment supplied by the secondary.
d. Enclosed switches.
e. Enclosed circuit breakers.
f. Enclosed controllers.
g. Contactors.
h. Battery-inverter units.

END OF SECTION

SECTION 26 2416

PANELBOARDS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Distribution panelboards.
2. Lighting and appliance branch-circuit panelboards.

1.3 DEFINITIONS

A. ATS: Acceptance testing specification.

B. GFCI: Ground-fault circuit interrupter.

C. GFEP: Ground-fault equipment protection.

D. HID: High-intensity discharge.

E. MCCB: Molded-case circuit breaker.

F. SPD: Surge protective device.

G. VPR: Voltage protection rating.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of panelboard.

1. Include materials, switching and overcurrent protective devices, SPDs, accessories, and components indicated.
2. Include dimensions and manufacturers' technical data on features, performance, electrical characteristics, ratings, and finishes.

B. Shop Drawings: For each panelboard and related equipment.

1. Include dimensioned plans, elevations, sections, and details.
2. Show tabulations of installed devices with nameplates, conductor termination sizes, equipment features, and ratings.
3. Detail enclosure types including mounting and anchorage, environmental protection, knockouts, corner treatments, covers and doors, gaskets, hinges, and locks.

4. Detail bus configuration, current, and voltage ratings.
5. Short-circuit current rating of panelboards and overcurrent protective devices.
6. Include evidence of NRTL listing for SPD as installed in panelboard.
7. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
8. Include wiring diagrams for power, signal, and control wiring.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For panelboards and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

   1. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.

1.6 QUALITY ASSURANCE

A. Manufacturer Qualifications: ISO 9001 or 9002 certified.

B. Source Limitations:

   1. Obtain panelboards, overcurrent protective devices, components and associates form the same manufacturer as:
      a. Fusible and non-fusible switches.
      b. Molded case circuit breakers.
      c. Enclosed controllers.
      d. Switchboards.
      e. Motor control centers.
      f. Enclosed busway.
      g. Low voltage transformers.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Remove loose packing and flammable materials from inside panelboards; install temporary electric heating (250 W per panelboard) to prevent condensation.

B. Handle and prepare panelboards for installation according to NECA 407.

1.8 FIELD CONDITIONS

A. Environmental Limitations:

   1. Do not deliver or install panelboards until spaces are enclosed and weathertight, wet work in spaces is complete and dry, work above panelboards is complete, and temporary HVAC system is operating and maintaining ambient temperature and humidity conditions at occupancy levels during the remainder of the construction period.
   2. Rate equipment for continuous operation under the following conditions unless otherwise indicated:

      a. Ambient Temperature: Not exceeding 23 deg F to plus 104 deg F.

b. Altitude: Not exceeding 6600 feet.

B. Service Conditions: NEMA PB 1, usual service conditions, as follows:

1. Ambient temperatures within limits specified.
2. Altitude not exceeding 6600 feet.

C. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:

1. Notify Architect and Owner no fewer than seven days in advance of proposed interruption of electric service.
2. Do not proceed with interruption of electric service without Architect's or Owner's written permission.
3. Comply with NFPA 70E.

1.9 WARRANTY

A. Manufacturer's Warranty: Manufacturer agrees to repair or replace panelboards that fail in materials or workmanship within specified warranty period.

1. Panelboard Warranty Period: 18 months from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PANELBOARDS AND LOAD CENTERS COMMON REQUIREMENTS

A. Product Selection for Restricted Space: Drawings indicate maximum dimensions for panelboards including clearances between panelboards and adjacent surfaces and other items. Comply with indicated maximum dimensions.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Comply with NEMA PB 1.

D. Comply with NFPA 70.

E. Enclosures: Flush and Surface-mounted, dead-front cabinets.

1. Rated for environmental conditions at installed location.

a. Indoor Dry and Clean Locations: NEMA 250, Type 1.

2. Height: 84 inches maximum.
3. Front: Secured to box with concealed trim clamps. For surface-mounted fronts, match box dimensions; for flush-mounted fronts, overlap box. Trims shall cover all live parts and shall have no exposed hardware.
4. Finishes:

a. Panels and Trim: Steel, factory finished immediately after cleaning and pretreating with manufacturer's standard two-coat, baked-on finish consisting of prime coat and thermosetting topcoat.
b. Back Boxes: Galvanized steel.

F. Incoming Mains:

1. Location: Top.
2. Main Breaker: Main lug interiors up to 400 amperes shall be field convertible to main breaker.

G. Phase, Neutral, and Ground Buses:

1. Material: Tin-plated aluminum or hard-drawn copper, 98 percent conductivity.

   a. Plating shall run entire length of bus.
   b. Bus shall be fully rated the entire length.

2. Interiors shall be factory assembled into a unit. Replacing switching and protective devices shall not disturb adjacent units or require removing the main bus connectors.
3. Equipment Ground Bus: Adequate for feeder and branch-circuit equipment grounding conductors; bonded to box.
4. Isolated Ground Bus (for those panels scheduled on drwaings): Adequate for branch-circuit isolated ground conductors; insulated from box.
5. Full-Sized Neutral: Equipped with full-capacity bonding strap for service entrance applications. Mount electrically isolated from enclosure. Do not mount neutral bus in gutter.
6. Extra-Capacity Neutral Bus: Neutral bus rated 200 percent of phase bus and listed and labeled by an NRTL acceptable to authority having jurisdiction, as suitable for nonlinear loads in electronic-grade panelboards and others designated on Drawings. Connectors shall be sized for double-sized or parallel conductors as indicated on Drawings. Do not mount neutral bus in gutter.

H. Conductor Connectors: Suitable for use with conductor material and sizes.

1. Material: [**Tin-plated aluminum**] [**Hard-drawn copper, 98 percent conductivity**].
2. Terminations shall allow use of 75 deg C rated conductors without derating.
3. Size: Lugs suitable for indicated conductor sizes, with additional gutter space, if required, for larger conductors.
4. Main and Neutral Lugs: Mechanical type, with a lug on the neutral bar for each pole in the panelboard.
5. Ground Lugs and Bus-Configured Terminators: Mechanical type, with a lug on the bar for each pole in the panelboard.
6. Feed-Through Lugs: Mechanical type, suitable for use with conductor material. Locate at opposite end of bus from incoming lugs or main device.
7. Subfeed (Double) Lugs: Mechanical type suitable for use with conductor material. Locate at same end of bus as incoming lugs or main device.
8. Extra-Capacity Neutral Lugs: Rated 200 percent of phase lugs mounted on extra-capacity neutral bus.

I. Panelboard Short-Circuit Current Rating: Fully rated to interrupt symmetrical short-circuit current available at terminals. Assembly listed by an NRTL for 100 percent interrupting capacity.

1. Panelboards and overcurrent protective devices rated 240 V or less shall have short-circuit ratings as shown on Drawings, but not less than 10,000 A rms symmetrical.

2. Panelboards and overcurrent protective devices rated above 240 V and less than 600 V shall have short-circuit ratings as shown on Drawings, but not less than 14,000 A rms symmetrical.

2.2 POWER PANELBOARDS (DISTRIBUTION PANELBOARDS)

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton.
2. ESL Power Systems, Inc.
3. General Electric Company; GE Energy Management - Electrical Distribution.
4. Siemens Energy.
5. Square D.

B. Panelboards: NEMA PB 1, distribution type.

C. Doors: Secured with vault-type latch with tumbler lock; keyed alike.

1. For doors more than 36 inches high, provide two latches, keyed alike.

D. Mains: Circuit breaker.

E. Branch Overcurrent Protective Devices for Circuit-Breaker Frame Sizes 125 A and Smaller: Bolt-on circuit breakers.

F. Branch Overcurrent Protective Devices for Circuit-Breaker Frame Sizes Larger Than 125 A: Bolt-on circuit breakers.

2.3 LIGHTING AND APPLIANCE BRANCH-CIRCUIT PANELBOARDS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton.
2. General Electric Company; GE Energy Management - Electrical Distribution.
3. Siemens Energy.
4. Square D.

B. Panelboards: NEMA PB 1, lighting and appliance branch-circuit type.

C. Mains: Circuit breaker or lugs only.

D. Branch Overcurrent Protective Devices: Bolt-on circuit breakers, replaceable without disturbing adjacent units.

E. Doors: Concealed hinges; secured with flush latch with tumbler lock; keyed alike.

2.4 DISCONNECTING AND OVERCURRENT PROTECTIVE DEVICES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton.
2. General Electric Company; GE Energy Management - Electrical Distribution.
3. Siemens Energy.
4. Square D.

B. MCCB: Comply with UL 489, with interrupting capacity to meet available fault currents.

1. Thermal-Magnetic Circuit Breakers:

a. Inverse time-current element for low-level overloads.
b. Instantaneous magnetic trip element for short circuits.
c. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.

2. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
3. Electronic Trip Circuit Breakers:

a. RMS sensing.
b. Field-replaceable rating plug or electronic trip.
c. Digital display of settings, trip targets, and indicated metering displays.
d. Multi-button keypad to access programmable functions and monitored data.
e. Ten-event, trip-history log. Each trip event shall be recorded with type, phase, and magnitude of fault that caused the trip.
f. Integral test jack for connection to portable test set or laptop computer.
g. Field-Adjustable Settings:

1) Instantaneous trip.
2) Long- and short-time pickup levels.
3) Long and short time adjustments.
4) Ground-fault pickup level, time delay, and I squared T response.

4. GFCI Circuit Breakers: Single- and double-pole configurations with Class A ground-fault protection (6-mA trip).
5. GFEP Circuit Breakers: Class B ground-fault protection (30-mA trip).
6. Subfeed Circuit Breakers: Vertically mounted.
7. MCCB Features and Accessories:

a. Standard frame sizes, trip ratings, and number of poles.
b. Breaker handle indicates tripped status.
c. UL listed for reverse connection without restrictive line or load ratings.
d. Lugs: Mechanical style, suitable for number, size, trip ratings, and conductor materials.
e. Ground-Fault Protection: Integrally mounted relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.

2.5 IDENTIFICATION

A. Panelboard Label: Manufacturer's name and trademark, voltage, amperage, number of phases, and number of poles shall be located on the interior of the panelboard door.

B. Breaker Labels: Faceplate shall list current rating, UL and IEC certification standards, and AIC rating.

C. Circuit Directory: Computer-generated circuit directory mounted inside panelboard door with transparent plastic protective cover.

1. Circuit directory shall identify specific purpose with detail sufficient to distinguish it from all other circuits.

2.6 ACCESSORY COMPONENTS AND FEATURES

A. Accessory Set: Include tools and miscellaneous items required for overcurrent protective device test, inspection, maintenance, and operation.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verify actual conditions with field measurements prior to ordering panelboards to verify that equipment fits in allocated space in, and comply with, minimum required clearances specified in NFPA 70.

B. Receive, inspect, handle, and store panelboards according to NECA 407.

C. Examine panelboards before installation. Reject panelboards that are damaged, rusted, or have been subjected to water saturation.

D. Examine elements and surfaces to receive panelboards for compliance with installation tolerances and other conditions affecting performance of the Work.

E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Coordinate layout and installation of panelboards and components with other construction that penetrates walls or is supported by them, including electrical and other types of equipment, raceways, piping, encumbrances to workspace clearance requirements, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Comply with NECA 1.

C. Install panelboards and accessories according to NECA 407.

D. Equipment Mounting:

1. Attach panelboard to the vertical finished or structural surface behind the panelboard.

E. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from panelboards.

F. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."

G. Mount top of trim 90 inches above finished floor unless otherwise indicated.

H. Mount panelboard cabinet plumb and rigid without distortion of box.

I. Mount recessed panelboards with fronts uniformly flush with wall finish and mating with back box.

J. Mount surface-mounted panelboards to steel slotted supports 1 1/4 inch in depth. Orient steel slotted supports vertically.

K. Install overcurrent protective devices and controllers not already factory installed.

1. Set field-adjustable, circuit-breaker trip ranges.
2. Tighten bolted connections and circuit breaker connections using calibrated torque wrench or torque screwdriver per manufacturer's written instructions.

L. Make grounding connections and bond neutral for services and separately derived systems to ground. Make connections to grounding electrodes, separate grounds for isolated ground bars, and connections to separate ground bars.

M. Install filler plates in unused spaces.

N. Where flush mounted panelboards are installed, stub four 1-inch empty conduits from panelboard into accessible ceiling space or space designated to be ceiling space in the future. Stub four 1-inch empty conduits into raised floor space or below slab not on grade.

3.3 IDENTIFICATION

A. Identify field-installed conductors, interconnecting wiring, and components; install warning signs complying with requirements in Section 260553 "Identification for Electrical Systems."

B. Create a directory to indicate installed circuit loads; incorporate Owner's final room designations. Obtain approval before installing. Handwritten directories are not acceptable. Install directory inside panelboard door.

C. Panelboard Nameplates: Label each panelboard with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

D. Device Nameplates: Label each branch circuit device in power panelboards with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.4 GROUND FAULT INTERRUPTING PROTECTION

A. Provide ground fault interrupting type circuit protection for the following equipment:

1. Service outlets within 25’ of HVAC and refrigeration equipment.
2. Heat tape.

3.5 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Perform each visual and mechanical inspection and electrical test for low-voltage air circuit breakers stated in NETA ATS, Paragraph 7.6 Circuit Breakers. Do not perform optional tests. Certify compliance with test parameters.
2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

B. Panelboards will be considered defective if they do not pass tests and inspections.

3.6 ADJUSTING

A. Set field-adjustable circuit-breaker trip ranges.

END OF SECTION

SECTION 26 2713

ELECTRICITY METERING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes work to accommodate utility company revenue meters.

1.3 ACTION SUBMITTALS

A. Product Data:

1. For metering infrastructure components.

1.4 FIELD CONDITIONS

A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Architect and Owner shall be notified and issued written permission no fewer than seven days in advance of proposed interruption of electrical service.

1.5 COORDINATION

A. Electrical Service Connections:

1. Coordinate with utility companies and utility-furnished components.

a. Comply with requirements of utility providing electrical power services.
b. Coordinate installation and connection of utilities and services, including provision for electricity-metering components.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Comply with UL 916.

2.2 UTILITY METERING INFRASTRUCTURE

A. Install metering accessories furnished by the utility company, complying with its requirements.

B. Current-Transformer Cabinets: Comply with requirements of electrical-power utility company.

C. Meter Sockets:

1. Comply with requirements of electrical-power utility company.
2. Meter Sockets: Steady-state and short-circuit current ratings shall meet indicated circuit ratings.

D. Arc-Flash Warning Labels;

1. Labels: Comply with requirements for "Self-Adhesive Equipment Labels" and "Signs" in Section 260553 "Identification for Electrical Systems." Apply a 3-1/2-by-5-inch thermal transfer label of high-adhesion polyester for each work location included in the analysis. Labels shall be machine printed, with no field-applied markings.

a. The label shall have an orange header with the wording, "WARNING, ARC-FLASH HAZARD," and shall include the following information taken directly from the arc-flash hazard analysis:

1) Location designation.
2) Nominal voltage.
3) Flash protection boundary.
4) Hazard risk category.
5) Incident energy.
6) Working distance.
7) Engineering report number, revision number, and issue date.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with equipment installation requirements in NECA 1.

B. Install meters furnished by utility company. Install raceways and equipment according to utility company's written instructions. Provide empty conduits for metering leads and extend grounding connections as required by utility company.

C. Install arc-flash labels as required by NFPA 70.

D. Wiring Method:

1. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
2. Minimum conduit size shall be 1/2 inch.

3.2 IDENTIFICATION

A. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

END OF SECTION

SECTION 26 2726

WIRING DEVICES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Straight-blade convenience and isolated-ground receptacles.
2. GFCI receptacles.

1.3 DEFINITIONS

A. Abbreviations of Manufacturers' Names:

1. Cooper: Cooper Wiring Devices; Division of Cooper Industries, Inc.
2. Hubbell: Hubbell Incorporated: Wiring Devices-Kellems.
3. Leviton: Leviton Mfg. Company, Inc.
4. Pass & Seymour: Pass& Seymour/Legrand.

B. BAS: Building automation system.

C. EMI: Electromagnetic interference.

D. GFCI: Ground-fault circuit interrupter.

E. Pigtail: Short lead used to connect a device to a branch-circuit conductor.

F. RFI: Radio-frequency interference.

G. SPD: Surge protective device.

H. UTP: Unshielded twisted pair.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For wiring devices to include in all manufacturers' packing-label warnings and instruction manuals that include labeling conditions.

PART 2 - PRODUCTS

2.1 GENERAL WIRING-DEVICE REQUIREMENTS

A. Wiring Devices, Components, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Comply with NFPA 70.

C. Devices that are manufactured for use with modular plug-in connectors may be substituted under the following conditions:

1. Connectors shall comply with UL 2459 and shall be made with stranding building wire.
2. Devices shall comply with the requirements in this Section.

D. Source Limitations: Obtain each type of wiring device and associated wall plate from single source from single manufacturer.

2.2 STRAIGHT-BLADE RECEPTACLES

A. Duplex Convenience Receptacles: 125 V, 20 A; comply with NEMA WD 1, NEMA WD 6 Configuration 5-20R, UL 498, and FS W-C-596.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Eaton (Arrow Hart).
   b. Hubbell Incorporated; Wiring Device-Kellems.
   c. Leviton Manufacturing Co., Inc.
   d. Pass & Seymour/Legrand (Pass & Seymour).

2.3 GFCI RECEPTACLES

A. General Description:

1. 125 V, 20 A, straight blade, feed-through type.
2. Comply with NEMA WD 1, NEMA WD 6 Configuration 5-20R, UL 498, UL 943 Class A, and FS W-C-596.
3. Include indicator light that shows when the GFCI has malfunctioned and no longer provides proper GFCI protection.

B. Duplex GFCI Convenience Receptacles:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Eaton (Arrow Hart).
   b. Hubbell Incorporated; Wiring Device-Kellems.
   c. Leviton Manufacturing Co., Inc.
   d. Pass & Seymour/Legrand (Pass & Seymour).

2.4 WALL PLATES

A. Single, multi gang and combination types shall match corresponding wiring devices.

1. Plate-Securing Screws: Metal with head color to match plate finish.
2. Material for Finished Spaces: 0.035-inch-thick, satin-finished, Type 302 stainless steel.
3. Material for Unfinished Spaces: Galvanized steel.
4. Material for Damp Locations: Thermoplastic with spring-loaded lift cover, and listed and labeled for use in wet and damp locations.

B. Wet-Location, Weatherproof Cover Plates: NEMA 250, complying with Type 3R, weather-resistant thermoplastic with lockable cover.

2.5 FINISHES

A. Device Color:

1. Wiring Devices Connected to Normal Power System: White unless otherwise indicated or required by NFPA 70 or device listing.

B. Coverplate Color:

1. Coverplates for devices connected to normal power system: When thermos-plastic or nylon coverplates are specified, their color shall match device color.

C. The Architect / Engineer reserves the right to change the color at time of shop drawing review.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with NECA 1, including mounting heights listed in that standard, unless otherwise indicated.

B. Mounting Heights

1. Examine architectural details and elevations for heights indicated there. Coordinate mounting heights with wall treatment and finish.
2. Examine electrical drawings for heights indicated there.
3. Unless otherwise indicated:

    a. Receptacles - General: 18" AFF.
    b. Receptacles in Mechanical and Electrical Equipment Rooms: 40" AFF.
    c. Receptacles - Exterior: 24" above finished grade.

4. Mounting heights given above shall be to the center line of the device.
5. In block walls, locate device in either bottom or top of the block course nearest to the height indicated.
6. In brick walls, mount receptacles in the horizontal position in the brick course nearest to the height indicated.
7. Where receptacles are indicated to be installed above counters, mount in the horizontal position 4" from top of back splash to bottom of box.

C. Coordination with Other Trades:

1. Protect installed devices and their boxes. Do not place wall finish materials over device boxes and do not cut holes for boxes with routers that are guided by riding against outside of boxes.
2. Keep outlet boxes free of plaster, drywall joint compound, mortar, cement, concrete, dust, paint, and other material that may contaminate the raceway system, conductors, and cables.
3. Install device boxes in brick or block walls so that the cover plate does not cross a joint unless the joint is troweled flush with the face of the wall.
4. Install wiring devices after all wall preparation, including painting, is complete.

D. Conductors:

1. Do not strip insulation from conductors until right before they are spliced or terminated on devices.
2. Strip insulation evenly around the conductor using tools designed for the purpose. Avoid scoring or nicking of solid wire or cutting strands from stranded wire.
3. The length of free conductors at outlets for devices shall meet provisions of NFPA 70, Article 300, without pigtails.
4. Existing Conductors:

    a. Cut back and pigtail, or replace all damaged conductors.
    b. Straighten conductors that remain and remove corrosion and foreign matter.
    c. Pigtailing existing conductors is permitted, provided the outlet box is large enough.

E. Device Installation:

1. Replace devices that have been in temporary use during construction and that were installed before building finishing operations were complete.
2. Keep each wiring device in its package or otherwise protected until it is time to connect conductors.
3. Do not remove surface protection, such as plastic film and smudge covers, until the last possible moment.
4. Connect devices to branch circuits using pigtails that are not less than 6 inches in length.
5. When there is a choice, use side wiring with binding-head screw terminals. Wrap solid conductor tightly clockwise, two-thirds to three-fourths of the way around terminal screw.
6. Use a torque screwdriver when a torque is recommended or required by manufacturer.
7. When conductors larger than No. 12 AWG are installed on 15- or 20-A circuits, splice No. 12 AWG pigtails for device connections.
8. Tighten unused terminal screws on the device.
9. When mounting into metal boxes, remove the fiber or plastic washers used to hold device-mounting screws in yokes, allowing metal-to-metal contact.

F. Receptacle Orientation:

1. Install ground pin of vertically mounted receptacles up, and on horizontally mounted receptacles to the right.
2. Install hospital-grade receptacles in patient-care areas with the ground pin or neutral blade at the top.

G. Device Plates: Device plates shall fit tight against the finished walls and shall completely cover the openings in the walls for the boxes. Do not use oversized or extra-deep plates. Repair wall finishes and remount outlet boxes when standard device plates do not fit flush or do not cover rough wall opening. Device plates shall be attached and adjusted so they finish straight and level.

H. Dimmers:

1. Install dimmers within terms of their listing.
2. Verify that dimmers used for fan-speed control are listed for that application.
3. Install unshared neutral conductors on line and load side of dimmers according to manufacturers' device listing conditions in the written instructions.

I. Arrangement of Devices: Unless otherwise indicated, mount flush, with long dimension vertical and with grounding terminal of receptacles on top. Group adjacent switches under single, multigang wall plates.

J. Adjust locations of floor service outlets and service poles to suit arrangement of partitions and furnishings.

3.2 GFCI RECEPTACLES

A. Install non-feed-through-type GFCI receptacles where protection of downstream receptacles is not required.

3.3 GROUND FAULT INTERRUTING RECEPTACLES

A. Where drawing or specifications call for 20 amp, 120 volt receptacles in the following locations, provide ground fault interrupting type receptacles.

1. Outdoors.
2. Rooftops.

3.4 IDENTIFICATION

A. Comply with Section 260553 "Identification for Electrical Systems."

1. Receptacles and Switches: Provide all outlet and switch coverplates with identification labels showing panelboard designation and circuit breaker number connected to device.

    a. Normal Circuits: Black letters indicating panel and circuit number on clear background applied to front of coverplate. Minimum letter height 3/16".

2. Labels shall be attached to coverplates with pressure-sensitive adhesive. Devices installed in multi-outlet, surface raceways shall be provided with labels.

3.5 FIELD QUALITY CONTROL

A. Test Instruments: Use instruments that comply with UL 1436.

B. Test Instrument for Convenience Receptacles: Digital wiring analyzer with digital readout or illuminated digital-display indicators of measurement.

C. Tests for Convenience Receptacles:

1. Line Voltage: Acceptable range is 105 to 132 V.
2. Percent Voltage Drop under 15-A Load: A value of 6 percent or higher is unacceptable.
3. Ground Impedance: Values of up to 2 ohms are acceptable.
4. GFCI Trip: Test for tripping values specified in UL 1436 and UL 943.
5. Using the test plug, verify that the device and its outlet box are securely mounted.
6. Tests shall be diagnostic, indicating damaged conductors, high resistance at the circuit breaker, poor connections, inadequate fault current path, defective devices, or similar problems. Correct circuit conditions, remove malfunctioning units and replace with new ones, and retest as specified above.

D. Wiring device will be considered defective if it does not pass tests and inspections.

END OF SECTION

SECTION 26 2913

ENCLOSED CONTROLLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes the following enclosed controllers rated 600 V and less:

1. Full-voltage manual.
2. Full-voltage magnetic.

1.3 DEFINITIONS

A. CPT: Control power transformer.

B. MCCB: Molded-case circuit breaker.

C. MCP: Motor circuit protector.

D. N.C.: Normally closed.

E. N.O.: Normally open.

F. OCPD: Overcurrent protective device.

G. SCR: Silicon-controlled rectifier.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of enclosed controller. Include manufacturer's technical data on features, performance, electrical characteristics, ratings, and enclosure types and finishes.

B. Shop Drawings: For each enclosed controller. Include dimensioned plans, elevations, sections, details, and required clearances and service spaces around controller enclosures.

1. Show tabulations of the following:

a. Each installed unit's type and details.
b. Factory-installed devices.
c. Nameplate legends.
d. Short-circuit current rating of integrated unit.
e. Listed and labeled for integrated short-circuit current (withstand) rating of OCPDs in combination controllers by an NRTL acceptable to authorities having jurisdiction.

f. Features, characteristics, ratings, and factory settings of individual OCPDs in combination controllers.

2. Wiring Diagrams: For power, signal, and control wiring.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For enclosed controllers to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

1. Routine maintenance requirements for enclosed controllers and installed components.
2. Manufacturer's written instructions for testing and adjusting circuit breaker and MCP trip settings.
3. Manufacturer's written instructions for setting field-adjustable overload relays.
4. Manufacturer's written instructions for testing, adjusting, and reprogramming reduced-voltage solid-state controllers.

1.6 MATERIALS MAINTENANCE SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fuses for Fused Switches: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
2. Control Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two of each size and type.
3. Indicating Lights: Two of each type and color installed.

1.7 QUALITY ASSURANCE

A. Source Limitations:

1. Obtain enclosed controllers through one source from a single manufacturer.
2. Obtain enclosed controllers from the same manufacturer as:

a. Fusible and non-fusible switches.
b. Molded case circuit breakers.
c. Switchboards.
d. Distribution panelboards.
e. Branch circuit panelboards.
f. Motor control centers.
g. Enclosed busway.
h. Low voltage transformers.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Comply with NFPA 70.

D. IEEE Compliance: Fabricate and test enclosed controllers according to IEEE 344 to withstand seismic forces defined in Section 260548.16 "Seismic Controls for Electrical Systems."

1.8 DELIVERY, STORAGE, AND HANDLING

A. Store enclosed controllers indoors in clean, dry space with uniform temperature to prevent condensation. Protect enclosed controllers from exposure to dirt, fumes, water, corrosive substances, and physical damage.

1.9 PROJECT CONDITIONS

A. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:

1. Ambient Temperature: Not less than minus 22 deg F and not exceeding 104 deg F.
2. Altitude: Not exceeding 6600 feet.

B. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Notify Architect and Owner no fewer than seven days in advance of proposed interruption of electrical systems.
2. Indicate method of providing temporary utilities.
3. Do not proceed with interruption of electrical systems without Architect's written permission.
4. Comply with NFPA 70E.

1.10 COORDINATION

A. Coordinate layout and installation of enclosed controllers with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

PART 2 - PRODUCTS

2.1 FULL-VOLTAGE CONTROLLERS

A. General Requirements for Full-Voltage Controllers: Comply with NEMA ICS 2, general purpose, Class A.

B. Fractional Horsepower Manual Controllers: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off, on, or tripped.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

    a. Eaton.

b. General Electric Company.
c. Rockwell Automation, Inc.
d. Siemens Industry, Inc.
e. Square D; by Schneider Electric.

2. Configuration: Nonreversing.
3. Overload Relays: Inverse-time-current characteristics; NEMA ICS 2, Class 10 tripping characteristics; heaters matched to nameplate full-load current of actual protected motor; external reset push button; melting alloy type.
4. Flush or surface mounting as shown on plan.
5. Red pilot light.

C. Magnetic Controllers: Full voltage, across the line, electrically held.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Eaton.
b. General Electric Company.
c. Rockwell Automation, Inc.
d. Siemens Industry, Inc.
e. Square D; by Schneider Electric.

2. Configuration: Nonreversing.

3. Contactor Coils: Pressure-encapsulated type.

a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.

4. Power Contacts: Totally enclosed, double-break, silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
5. Control Circuits: 120-V ac; obtained from integral CPT, with primary and secondary fuses, with CPT of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.

a. CPT Spare Capacity: 100 VA.

6. Melting Alloy Overload Relays:

a. Inverse-time-current characteristic.
b. Class 20 tripping characteristic.
c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

7. Solid-State Overload Relay:

a. Switch or dial selectable for motor running overload protection.
b. Sensors in each phase.
c. Class 20 tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
d. Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
e. Analog communication module.

8. External overload reset push button.

D. Combination Magnetic Controller: Factory-assembled combination of magnetic controller, OCPD, and disconnecting means.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Eaton.
b. General Electric Company.
c. Rockwell Automation, Inc.
d. Siemens Industry, Inc.
e. Square D; by Schneider Electric.

2. Fusible Disconnecting Means:

a. NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate fuses.
b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

3. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

2.2 ENCLOSURES

A. Enclosed Controllers: NEMA ICS 6, to comply with environmental conditions at installed location.

1. Dry and Clean Indoor Locations: Type 1.
2. Outdoor Locations: Type 3R.
3. Kitchen or Wash-Down Areas: Type 4X, stainless steel.
4. Other Wet or Damp Indoor Locations: Type 4.

2.3 ACCESSORIES

A. General Requirements for Control Circuit and Pilot Devices: NEMA ICS 5; factory installed in controller enclosure cover unless otherwise indicated.

1. Push Buttons, Pilot Lights, and Selector Switches: Heavy-duty type.

B. N.C. N.O. auxiliary contact(s) (quantity as shown on schedule).

C. Control Relays: Auxiliary and adjustable solid-state time-delay relays.

D. Cover gaskets for Type 1 enclosures.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and surfaces to receive enclosed controllers, with Installer present, for compliance with requirements and other conditions affecting performance of the Work.

B. Examine enclosed controllers before installation. Reject enclosed controllers that are wet, moisture damaged, or mold damaged.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

A. Provide separately mounted motor controllers as scheduled and shown on the drawings.

B. Recess manual starters flush in walls in all finished areas. In mechanical equipment areas or areas with exposed conduit, furnish surface enclosure.

C. Provide separate hand-off auto selector switch with maintained contacts in separate enclosure adjacent to manual starters where shown on the drawings or noted in the starter schedule.

D. Provide combination magnetic starters for all multiple phase operated equipment, as indicated in the starter schedule. All starters shall be complete with pilot lights in cover, externally operated fused disconnect switch, fuses, and three (3) proper sized overload heaters as required. Furnish additional accessories, such as auxiliary contacts, on-off selector switches, hand-off auto selector switches and push button with the starter as indicated in the schedule. All push-button and hand-off auto selector switches shall have maintained contacts.

E. Provide all magnetic and manual starters with properly sized overload elements.

F. Furnish controllers with additional accessories, such as auxiliary contacts, on-off push buttons and hand-off auto selector switches with the starter as indicated in the schedule.

G. All magnetic starters shall be provided with control coils for 120 volt control voltage. Control transformers shall be furnished for 480 volt volt starters. Provide in-line fuse in secondary circuit of control transformer.

H. The schedule of starters as shown on the drawings shall indicate motor horse power, phase, voltage, starter size, starter type, auxiliary contacts, types of accessories; such as push buttons or hand-off-automatic switches.

3.3 INSTALLATION

A. Wall-Mounted Controllers: Install enclosed controllers on walls with tops at uniform height unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not at walls, provide freestanding racks complying with Section 260529 "Hangers and Supports for Electrical Systems."

B. Install fuses in each fusible-switch enclosed controller.

C. Install fuses in control circuits if not factory installed. Comply with requirements in Section 262813 "Fuses."

D. Install heaters in thermal overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.

E. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.

F. Comply with NECA 1.

3.4 IDENTIFICATION

A. Identify enclosed controllers, components, and control wiring. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

1. Label each enclosure with engraved nameplate.
2. Label each enclosure-mounted control and pilot device.

3.5 CONTROL WIRING INSTALLATION

A. Bundle, train, and support wiring in enclosures.

3.6 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Acceptance Testing Preparation:

1. Test insulation resistance for each enclosed controller, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

C. Tests and Inspections:

1. Inspect controllers, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Test continuity of each circuit.
3. Verify that voltages at controller locations are within plus or minus 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify Architect before starting the motor(s).
4. Test each motor for proper phase rotation.
5. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
6. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

7. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

D. Enclosed controllers will be considered defective if they do not pass tests and inspections.

3.7 ADJUSTING

A. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

B. Adjust overload-relay heaters or settings if power factor correction capacitors are connected to the load side of the overload relays.

3.8 PROTECTION

A. Replace controllers whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.9 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain enclosed controllers.

END OF SECTION