

# Houstonfirst<sup>SM</sup>

**DATE:** May 5, 2025

**SUBJECT:** Letter of Clarification

**RE:** Miller Outdoor Theatre Stage and HVAC Replacement Invitation to Bid

**TO:** All Prospective Bidders

Houston First Corporation (“HFC”) issues this Letter of Clarification regarding the referenced Miller Outdoor Theatre Stage and HVAC Replacement Invitation to Bid to make the following clarifications and answer questions timely received in the manner set forth below:

**Question 1:** Is there going to be a Division 23 spec section issued on this project?

Answer: Mechanical specifications were mistakenly omitted from the bid package. Please see Addendum One below.

**Question 2:** Is there a controls spec? We did not see anything for Division 25.

Answer: Controls, since it is VRF, are included in Divisions 23 in Addendum One below.

**Question 3:** Can we bid the mechanical and exclude the stage replacement?

Answer: No.

**Question 4:** Do you have a preferred stage replacement contractor?

Answer: No.

**Question 5:** May the contractor install a 6 ft. high chain link fence to enclose the theatre seating so that there is no public access to the pavilion/stage?

Answer: Yes. HFC would prefer that any such fencing include a privacy screen.

**Question 6:** Are the restrooms behind the theatre available for use during the hours of 6:00AM – 3:30PM Monday – Friday?

Answer: Yes. The restrooms will be open to meet the contractor’s schedule.

**Question 7:** There is no specification section for mechanical division, is there one available?

Answer: Mechanical specifications were mistakenly omitted from the bid package. Please see Addendum One below.

**Question 8:** Who is the current BAS service company overseeing the controls for HVAC?

Answer: There is no current BAS service company, but HFC is implementing Carrier I-Vu across the system.

**Question 9:** Who is the current BAS service company overseeing the controls for HVAC?

Answer: There are no preferred AV Integrators. Any Integrator may bid the project, but they must first submit their qualifications. The submittal requirements are listed in specification section 274100. Four local Houston contractors who have previously submitted their qualifications: LD Systems, Ford AV, Covenant Communications, and Continuant.

**Question 10:** May a contingency of \$50,000 be placed across all contractors for the underground AV scope should more than noted cabling be discovered. Note 1 of sheet AV-101 indicates that there may be additional cabling discovered when the floor is removed.

Answer: No, though concealed conditions is addressed under the construction contract.

**Question 11:** Sheet MI-001 under notes – N33 references IA-10X plans for device counts and locations. Where is this sheet located?

Answer: MI-001 is a reference sheet for the other MI sheets, if Note 33 is not referenced in the other sheet sequences then it is not used.

**Question 12:** Sheet MH-101 note two references electrical and AV, note tag on drawing shows AFMS scope.

Answer: Yes, coordinate between those contractors on how to fill in the gap between the AFMS and the concrete but allow AV and Electrical an airtight path.

**Question 13:** Sheet MD-101, plan northeast wing shows three units to demo. FCU-4, FCU-1, and AHU-3. We found that these are mislabeled compared to what is out in the field. Furthermore, FCU-4 seems to have been demolished/removed already.

Answer: FCU-1 which serves the crew area. The AHU-3 as well and unit (FCU-4) located in John's office. AHU-3 is shown to the side in plan view so you don't miss that these are on top of each other almost.

**Question 14:** Sheet A-501, detail 2 indicates a Stage LED Light note and to reference the Electrical drawings. There is no note on the electrical drawings calling out specifics for an LED light within the flooring.

Answer: RE: EP-101. Light fixture type "L1"

**Question 15:** May we schedule more time to review the facility to further review and coordinate electrical utilities and, if so, who should we contact?

Answer: Yes. Please contact Shawn Hauptmann ([shawn.hauptmann@houstonfirst.com](mailto:shawn.hauptmann@houstonfirst.com)) or Nicole Young ([nicole.young@houstonfirst.com](mailto:nicole.young@houstonfirst.com)).

**Question 16:** Sheet EQ-102 new CU-3 & 4 are shown to be fed by the same circuit (#16) out of MSB. Should the new CU-4 be fed from another independent source? This is not shown in the MSB panel schedule?

Answer: No, the design intent is for MSB-16 to feed both CU-3, CU-4 units as shown on EQ-102.

**Question 17:** Sheet E-401 detail 1 – new FCU 1 does not have any notes for direction. This unit is shown to be demolished under the mechanical demo sheet.

Answer: Connect to circuit LB2-19,21 via 250V, 20A-2P motor rated switch (same circuit as FCU-2,3,4,5)

**Question 18:** Sheet ED-101 and EP-101 for Office 31 show to demo and replace AHU 2 per the mechanical drawings, but no direction on the electrical sheets is given.

Answer: Disconnect AHU-2 and remove associated electrical, disconnect switch and control devices. Retain existing conduit/wire for reuse to reconnect via 250V, 20A-2P motor rated switch to new AHU-2.

This Letter of Clarification becomes part of the referenced Invitation to Bid automatically upon issuance and shall supersede any previous specifications and/or provisions in conflict therewith. By submitting their bid, bidders are deemed to have reviewed this Letter of Clarification and incorporated its content into their submission.

## Addendum

<b>Distribution</b>	<input checked="" type="checkbox"/> Owner	<input checked="" type="checkbox"/> Consultant(s)	<input checked="" type="checkbox"/> Bidders	<input type="checkbox"/> Other ..
<b>From</b>	Chris Hopkins, Page Southerland Page, Inc. 1111 Louisiana St., Suite 1 Houston, TX 77002	<b>Owner</b>	Deyanira Rodriguez Associate Director, Capital Projects Houston First	
<b>Project</b>	Miller Outdoor Theatre	<b>Architect's Project No.</b>	422008.08	
<b>Date of Issue</b>	05/2/2025	<b>Addendum No.</b>	001	
<b>Contract For</b>	General Construction	<b>For Bids Due</b>		

### Seals



<b>Description</b>	This Addendum includes the following changes to the Work: 1. Mechanical Specifications
<b>Revised Documents</b>	This Addendum includes specification sections that have been added as of the date noted above. Please ADD these sections to your bidding documents.

### Specifications:

#### DIVISION 23 – HEATING, VENTILATION AND AIR CONDITIONING

230000	Basic Mechanical Requirements
230130	HVAC Air Duct Cleaning
230513	Common Motor Requirements for HVAC Equipment
230529	Hangers and Supports for HVAC Piping and Equipment
230548	Vibration Controls for HVAC Piping and Equipment
230553	Identifications for HVAC Piping and Equipment
230593	Testing, Adjusting and Balancing for HVAC
230713	Duct Insulation
230719	HVAC Piping Insulation
230800	Commissioning of HVAC
230900	HVAC Automation and Control

230923.12	Control Dampers
232300	Refrigerant Piping
232923	Variable Frequency Motor Controller
233113	Metal Ducts
233119	HVAC Casings
233300	Air Duct Accessories
233416	Centrifugal HVAC Fans
233713	Diffusers, Registers and Grilles
234100	Particulate Air Filtration
237312	Semi Custom Outdoor Air Filtration Units
238127	VRF Split-System Air-Conditioners

This Addendum is hereby incorporated into the Contract Documents for the Project referenced above, modifying and superseding any previously issued Contract Documents. Bidders must acknowledge receipt of **Addendum 001** in the bid form.

**DOCUMENT 000110 - TABLE OF CONTENTS**

Section	Section Title
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**INTRODUCTORY INFORMATION**

000101	Cover Page
000107	Professional Seals
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**DIVISION 01 - GENERAL REQUIREMENTS**

011000	Summary
012500	Substitution Procedures
012600	Contract Modification Procedures
012900	Payment Procedures
013100	Project Management and Coordination
013200	Construction Progress Documentation
013300	Submittal Procedures
013516	Alteration Project Procedures
014000	Quality Requirements
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015000	Temporary Facilities and Controls
016000	Product Requirements
017300	Execution
017419	Construction Waste Management and Disposal
017700	Closeout Procedures
017823	Operation and Maintenance Data
017839	Project Record Documents
017900	Demonstration and Training

**DIVISION 09 - FINISHES**

090561	Common Work Results for Flooring Preparation
096413	Wood Flooring - Nailed
099000	Painting and Coating

**DIVISION 23 – HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)**

<u>230000</u>	<u>Basic Mechanical Requirements</u>
<u>230130</u>	<u>HVAC Air Duct Cleaning</u>
<u>230513</u>	<u>Common Motor Requirements for HVAC Equipment</u>
<u>230529</u>	<u>Hangers and Supports for HVAC Piping and Equipment</u>
<u>230548</u>	<u>Vibration Controls for HVAC Piping and Equipment</u>
<u>230553</u>	<u>Identification for HVAC Piping and Equipment</u>
<u>230593</u>	<u>Testing, Adjusting, and Balancing for HVAC</u>
<u>230713</u>	<u>Duct Insulation</u>
<u>230719</u>	<u>HVAC Piping Insulation</u>
<u>230800</u>	<u>Commissioning of HVAC</u>
<u>230900</u>	<u>HVAC Automation and Control</u>
<u>230923.12</u>	<u>Control Dampers</u>
<u>232300</u>	<u>Refrigerant Piping</u>
<u>232923</u>	<u>Variable Frequency Motor Controller</u>
<u>233113</u>	<u>Metal Ducts</u>
<u>233119</u>	<u>HVAC Casings</u>
<u>233300</u>	<u>Air Duct Accessories</u>
<u>233416</u>	<u>Centrifugal HVAC Fans</u>

<u>233713</u>	<u>Diffusers, Registers, and Grilles</u>
<u>234100</u>	<u>Particulate Air Filtration</u>
<u>237312</u>	<u>Semi Custom Outdoor Air Handling Units</u>
<u>238127</u>	<u>VRF Split-System Air-Conditioners</u>

**DIVISION 26 - ELECTRICAL**

260500	Common Work Results for Electrical
260505	Electrical Demolition
260519	Low-Voltage Electrical Power Conductors and Cables
260526	Grounding and Bonding for Electrical Systems
260529	Hanger and Supports for Electrical Systems
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## **SECTION 23 00 00 - BASIC MECHANICAL REQUIREMENTS**

### **PART 1 - GENERAL**

#### 1.1 SECTION INCLUDES

- A. Basic Mechanical Requirements specifically applicable to Division 23 sections.

#### 1.2 GENERAL

- A. The Contractor shall execute all work hereinafter specified or indicated on accompanying drawings. Contractor shall provide all equipment necessary and usually furnished or required by code in connection with such work and systems whether or not mentioned specifically herein or on the drawings. The system must be complete and fully functional at time of "Substantial Completion".
- B. The Contractor shall be responsible for fitting his material and apparatus into the building and shall carefully lay out his work at the site to conform to the structural conditions, to avoid all obstructions, to conform to the details of the installation and thereby to provide an integrated satisfactory operating installation. The mechanical contractor is also responsible for coordinating with all other subcontractors on the job to ensure that the mechanical systems are not in conflict with nor are missing any other services from the other subcontractors in order to be a fully functioning system.
- C. The mechanical, electrical, and associated drawings are necessarily diagrammatic by their nature, and are not intended to show every connection in detail or every pipe or conduit in its exact location. These details are subject to the requirements of standards referenced elsewhere in these specifications, and structural and architectural conditions. The Contractor shall carefully investigate structural and finish conditions and shall coordinate the separate trades in order to avoid interference between the various phases of work. Work shall be organized and laid out so that it will be concealed in furred chases and suspended ceilings, etc., in finished portions of the building, unless specifically noted to be exposed. All exposed work shall be installed parallel or perpendicular to the lines of the building unless otherwise noted.
- D. When the mechanical and electrical drawings do not give exact details as to the elevation of pipe, conduit and ducts, the Contractor shall physically arrange the systems to fit in the space available at the elevations intended with proper grades for the functioning of the system involved as well as providing proper clearances for all service areas per manufacturers instructions and "Listing" for the equipment. Piping, exposed conduit and the duct systems are generally intended to be installed true and square to the building construction and located as high as possible against the structure. The drawings do not show all required offsets, control lines, pilot lines and other location details. Work shall be concealed in all finished areas.

- #### 1.3 DEFINITIONS (Note: These definitions are included here to clarify the direction and intention of this specification. The list given here is not by any means complete. For further clarification as required, contractor shall contact the designated Owner's representative.)

- A. Concealed/exposed: Concealed areas are those that cannot be seen by the building occupants. Exposed areas are all areas that are exposed to view by the building occupants, including under counters, inside cabinets and closets, plus all mechanical rooms.
- B. General Requirements: The provisions of requirements of other Division 01 sections apply to entire work of contract and, where so indicated, to other elements that are included in project. Basic contract definitions are included in the General Conditions.
- C. Indicated: The term "indicated" is a cross reference to graphic representations, notes or schedules on drawings, to other paragraphs or schedules in the specifications, and to similar means of recording requirements on contract documents. Where terms such as "shown," "noted," "scheduled," and "specified" are used in lieu of "indicated," it is for the purpose of helping reader locate the cross reference, and no limitation of location is intended except as specifically noted.
- D. Directed, requested, etc.: Where not otherwise explained, terms such as "directed," "requested," "authorized," "selected," "approved," "required," "accepted," and "permitted" mean "directed by Architect/Engineer," "requested by Architect/Engineer" and similar phrases. However, no such implied meaning will be interpreted to extend Architect's/Engineer's responsibility into Contractor's area of construction supervision and job safety.
- E. And/Or: Where "and/or" is used in these specifications or on the drawings, it shall mean "that situations exist where either one or both conditions occur or are required and shall not be interpreted to permit an option on the part of the Contractor.
- F. Approve: Where used in conjunction with Architect's/Engineer's response to submittals, requests, applications, inquiries, reports and claims by Contractor, the meaning of term "approved" will be held to limitations to Architect's/Engineer's responsibilities and duties as specified in General and Supplementary Conditions. In no case will "approval" by Architect/Engineer be interpreted as a release of Contractor from responsibilities to fulfill requirements of contract documents or to extend Architect's/Engineer's responsibility into Contractor's area of construction supervision and job safety.
- G. As required: Where "as required" is used in these specifications or on the drawings, it shall mean "that situations exist that are not necessarily described in detail or indicated that may cause the contractor certain complications in performing the work described or indicated. These complications entail the normal coordination activities expected of the Contractor where multiple trades are involved and new or existing construction causes deviations to otherwise simplistic approaches to the work to be performed. The term shall not be interpreted to permit an option on the part of the Contractor to achieve the end result."
- H. Furnish
  - 1. The term "furnish" is used to mean "supply and deliver to project site, ready for unloading, unpacking, assemble, installation, and similar operations."
  - 2. Where "furnish" applies to work for which the installation is not otherwise specified, "furnish" in such case shall mean "furnish and install."
- I. Install: The term "install" is used to describe operations at project site including "unloading, unpacking, assembly, erection, placing, anchoring, applying, working to dimension, finishing, curing, protecting, cleaning and similar operation."
- J. Provide: The term "provide" means "to furnish and install, complete and ready for intended use."

#### 1.4 PERMITS, UTILITY CONNECTIONS AND INSPECTIONS

- A. General: Refer to Division 01 for construction phasing and time increments. The contractor will be responsible for securing and paying for all trade permits and inspection fees for the work under their contracted scope.
- B. Fees and Costs: If, during the course of the construction, a need arises to buy utilities, the Contractor shall pay all fees attendant thereto. If city or privately owned utility piping or electrical cable needs to be extended, relocated, or terminated, the Contractor will pay all permits and construction/inspection fees associated with that particular work.
- C. Compliance: The Contractor shall comply in every respect with all requirements of National Fire Protection Association, local Fire Department regulations and utility company requirements. In no case does this relieve the Contractor of the responsibility of complying with these specifications and drawings where specified conditions are of higher quality than the requirements of the above-specified authorities. Where requirements of the specifications and drawings are more lenient than the requirements of the above authorities having jurisdiction, the Contractor shall make installations in compliance with the requirements of the above authorities with no extra compensation.

#### 1.5 CONTRACT DOCUMENTS

- A. All dimensional information related to new structures shall be taken from the appropriate drawings. All dimensional information related to existing facilities shall be taken from actual measurements made by the Contractor on the site.
- B. The interrelation of the specifications, the drawings, and the schedules are as follows: The specifications determine the nature and setting of the several materials, the drawings establish the quantities, dimensions and details, and the schedules give the performance characteristics. If the Contractor requires additional clarification, he shall request it in writing, following the contractually prescribed information flow requirements of the project.
- C. Should the drawings or specifications conflict within themselves, or with each other, the better quality, or greater size or quantity of work or materials shall be performed or furnished.

#### 1.6 ALTERNATES

- A. Alternates quoted on Bid Forms will be reviewed and accepted or rejected at the Owner's option.
- B. Coordinate related work and modify surrounding work as required.
- C. Any Alternate Proposals are summarized in Division 01 of the specifications. The Contractor is directed to refer to all sections of the specifications and drawings for this project to determine the exact extent and scope of the various Alternate Proposals as each pertains to the work of all trades.

#### 1.7 SUBMITTALS

- A. Include Products specified in the project Construction Documents. Any substitutions must have been made and approved before construction begins.

- B. Submit shop drawings and product data grouped to include complete submittals of related systems, products, and accessories.
- C. Mark dimensions and values in units to match those specified.
- D. Submit fabrication drawings whenever (1) equipment proposed varies from the basis of design indicated on the drawings, thus causing rearrangement of equipment space, (2) where tight spaces require extreme coordination between ductwork, piping, conduit, and other equipment, (3) where called for elsewhere in these specifications; and (4) where specifically requested by the Architect/Engineer. Fabrication drawings shall be made at no additional charge to the Owner or the Architect/Engineer.
- E. All required fabrication drawings for ductwork and piping, except as noted otherwise, shall be prepared at a scale of not less than 1/4" = 1'-0." Fabrication drawings for ductwork, air handling units, and sections in Mechanical Rooms shall be drawn at a minimum scale of 3/8" = 1'-0." Submit three blue-line prints of each fabrication drawing to the Architect/Engineer for review. Reproduction and submittal of the Construction Documents is not acceptable. The Architect/Engineer will review the drawing and return one print with comments.
- F. Engineer shall be given 14 days for review time of the submittal. Contractor shall account for this time in their schedule and not charge the owner or engineer for time delays.
- G. Approved submittals do not alleviate the contractor from all code requirements of the authority having jurisdiction.

#### 1.7 SUBSTITUTION OF MATERIALS AND EQUIPMENT

- A. Refer to General Conditions for substitution of materials and equipment.
- B. General: Within thirty days after the date of contract award or work order, whichever is later, and before purchasing or starting installation of materials or equipment, the Contractor shall submit for review, a complete list of suppliers, contractors and manufacturers for all materials and equipment that will be submitted for incorporation into the project. The list shall be arranged in accordance with the organization of the specifications. This initial list shall include the manufacturer's name and type or catalog number as required to identify the quality of material or equipment proposed. This list will be reviewed by the Engineer and the Owner and will be returned to the Contractor with comments as to which items are acceptable without further submittal data and which items will require detailed submittal data for further review and subsequent approval. The initial list shall be submitted as herein specified. Materials and equipment requiring detailed submittal data shall be submitted with sufficient data to indicate that all requirements of these specifications have been met and samples shall be furnished when requested. All manufacturers' data used as part of the submittal shall have all inapplicable features crossed out or deleted in a manner that will clearly indicate exactly what is to be furnished.
- C. It is not the intent of the drawings and/or specifications to limit products to any particular manufacturer nor to discriminate against an "APPROVED EQUAL" product as produced by another manufacturer. Some proprietary products are mentioned to set a definite standard for acceptance and to serve as a reference in comparison with other products. When a manufacturer's name appears in these specifications, it is not to be construed that the manufacturer is unconditionally acceptable as a provider of equipment for this project. The successful manufacturer or supplier shall meet all of the provisions of the appropriate specification(s).

- D. The specified products have been used in preparing the drawings and specifications and thus establish minimum qualities with which substitutes must at least equal to be considered acceptable. The burden of proof of equality rests with the Contractor. The decision of the Engineer is final.
- E. When requested by the Architect/Engineer, the Contractor shall provide a sample of the proposed substitute item. In some cases, samples of both the specified item and the proposed item shall be provided for comparison purposes.
- F. **Timeliness:** The burden of timeliness in the complete cycle of submittal data, shop drawings, and sample processing is on the Contractor. The Contractor shall allow a minimum of four (4) weeks time frame for review of each submission by the office of the design discipline involved after receipt of such submissions by that design discipline. The Contractor is responsible for allowing sufficient time in the construction schedule to cover the aforementioned cycles of data processing, including time for all resubmittal cycles on unacceptable materials, equipment, etc. covered by the data submitted. Construction delays and/or lack of timeliness in the above regard are the responsibility of the Contractor and will not be considered in any request for scheduled construction time extensions and/or additional costs to the Owner.
- G. All equipment installed on this project shall have local representation, local factory authorized service, and a local stock of repair parts.
- H. Acceptance of materials and equipment will be based on manufacturer's published data and will be tentative subject to the submission of complete shop drawings indicating compliance with the contract documents and that adequate and acceptable clearances for entry, servicing, and maintenance will exist. Acceptance of materials and equipment under this provision shall not be construed as authorizing any deviations from the specifications, unless the attention of the Architect/Engineer has been directed in writing to the specific deviations. Data submitted shall not contain unrelated information unless all pertinent information is properly identified.
- I. **Certification:** The Contractor shall carefully examine all data forwarded for approval and shall sign a certificate to the effect that the data has been carefully checked and found to be correct with respect to dimensions and available space and that the equipment complies with all requirements of the specifications.
- J. **Physical Size of Equipment:** Space is critical; therefore, equipment of larger sizes than shown, even though of specified manufacturer, will not be acceptable unless it can be demonstrated that ample space exists for proper installation, operation, and maintenance. This verification shall be performed by the contractor and the sign and certified submittal indicated that this has been performed by the contractor and no changes need to be made by the engineer or owner.
- K. **Materials and Equipment Lists:** A copy of the list of materials and equipment, the name of manufacturer, trade name, type, and catalog number shall be submitted to the Architect/Engineer. The lists shall be accompanied by a copy set of pictorial and descriptive data derived from the manufacturers' catalogs, sales literature, or incorporated in the shop drawings.
- L. Should a substitution be accepted, and should the substitute material prove defective, or otherwise unsatisfactory for the service intended within the guarantee period, this material or equipment shall be replaced with the material or equipment specified at no additional cost to the Owner.

## 1.8 MATERIALS AND WORKMANSHIP

- A. All materials, unless otherwise specified, shall be new, free from all defects, suitable for the intended use, and of the best quality of their respective kinds. Materials and equipment shall be installed in accordance with the manufacturer's recommendations and the best standard practice for the type of work involved. All work shall be executed by mechanics skilled in their respective trades, and the installations shall provide a neat, precise appearance. Materials and/or equipment damaged in shipment or otherwise damaged prior to installation shall not be repaired at the job site but shall be replaced with new materials and/or equipment.
- B. The responsibility for the furnishing of the proper equipment and/or material and seeing that it is installed as intended by the manufacturer, rests entirely upon the Contractor who shall request advice and supervisory assistance from the representative of specific manufacturers during the installation.

## 1.9 FLAME SPREAD PROPERTIES OF MATERIALS

- A. Materials and adhesives incorporated in this project shall conform to NFPA Standard 255, "Method of Test of Surface Burning Characteristics of Building Materials" and NFPA 90. The classification shall not exceed a flame spread rating of 25 for all materials, adhesives, finishes, etc., specified for each system, and shall not exceed a smoke developed rating of 50.
- B. Projects that are pursuing LEED or are LEED-EB type buildings also need materials used which comply with all the requirements of LEED.

## 1.10 REGULATORY REQUIREMENTS

- A. It is required that the installation shall meet the minimum standards prescribed in the latest editions of the following listed codes and standards, which are made a part of these specifications. All referenced codes and standards shall be those current at the date of issue of the design documents.
- B. National Fire Protection Association Standards (NFPA)
  - 1. NFPA No. 13, Sprinkler System, Installation
  - 2. NFPA No. 14, Standpipes and Hose Systems
  - 3. NFPA No. 20, Centrifugal Fire Pumps
  - 4. NFPA No. 37, Stationary Combustion Engines & Gas Turbines
  - 5. NFPA No. 45, Fire Protection for Laboratories Using Chemicals
  - 6. NFPA No. 51, Welding & Cutting, Oxygen-Fuel Gas Systems
  - 7. NFPA No. 54, Gas Appliances, Piping, National Fuel Gas Code
  - 8. NFPA No. 70, National Electrical Code
  - 9. NFPA No. 72D, Proprietary Signaling Systems
  - 10. NFPA No. 78, Lightning Protection Code
  - 11. NFPA No. 88A, Standard for Parking Structures
  - 12. NFPA No. 90A & 90B, Air Conditioning Systems
  - 13. NFPA No. 91, Blower & Exhaust Systems
  - 14. NFPA No. 99, Health Care Facilities
  - 15. NFPA No. 101, Life Safety Code
  - 16. NFPA No. 200, Series, Building Construction
  - 17. NFPA No. 211, Chimneys, Fireplaces, Vent Systems
  - 18. NFPA No. 241, Standard for Safeguarding Construction, Alteration and Demolition Operations

19. NFPA No. 255, Method of Test of Surface Burning Characteristics of Building Materials
  20. NFPA No. 258, Standard Research Test Method for Determining Smoke Generation of Solid Materials
- C. American National Standards Institute (ANSI)
1. A40.8, National Plumbing Code.
  2. B31.1, Power Piping.
  3. B9.1, Safety Code for Mechanical Refrigeration.
  4. ANSI B31.9, Building Services Piping.
- D. American Gas Association Publications (AGA): Directory of Approved Gas Appliances and Tested Accessories
- E. American Society of Mechanical Engineers (ASME): Boiler and Pressure Vessel Codes
- F. Air Conditioning and Refrigeration Institute Standards (ARI): All standards related to refrigeration and air conditioning equipment and piping furnished under these specifications.
- G. Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA): All current editions of applicable manuals and standards.
- H. Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA): All current editions of applicable manuals and standards.
- I. Air Moving and Conditioning Association (AMCA): All current editions of applicable manuals and standards.
- J. American Society of Testing Materials (ASTM): All current editions of applicable manuals and standards.
- K. American Water Works Association (AWWA): All current editions of applicable manuals and standards.
- L. National Electrical Manufacturers' Association (NEMA): All current editions of applicable manuals and standards.
- M. **City of #####**, Fire Department as may be applicable to construction on this site.
- N. International Building Code, (Includes the International Mechanical Code)
- O. Texas Occupational Safety Act: All applicable safety standards
- P. Occupational Safety and Health Act (OSHA)
- Q. ADA and ANSI Standards.
- R. USGBC, US Green Building Council Standards and requirements
- S. Refer to specification sections hereinafter bound for additional Codes and Standards.
- T. All materials and workmanship shall comply with all applicable city, state and national codes, specifications, and industry standards. In all cases where Underwriters Laboratories, Inc. has established standards for a particular type material, such material shall comply with these

standards. Evidence of compliance shall be the UL "label" or "listing" under Re-Examination Service.

- U. The Contract Documents are intended to comply with the aforementioned rules and regulations; however, some discrepancies may occur. Where such discrepancies occur, the Contractor shall immediately notify the Architect/Engineer in writing of said discrepancies and apply for an interpretation. Should the discovery and notification occur after the execution of a contract, any additional work required for compliance with said regulations shall be paid for as covered by Contractor who is responsible for the scope that needs clarified, providing no work of fabrication of materials has been accomplished in a manner of non-compliance. Should the Contractor fabricate and/or install materials and/or workmanship in such a manner that does not comply with the applicable codes, rules and regulations, the Contractor who performed such work shall bear all costs arising in correcting these deficiencies to comply with said rules and regulations.

#### 1.11 GENERAL MATERIALS AND EQUIPMENT REQUIREMENTS

- A. **Storage at Site:** The Contractor shall not receive material or equipment at the job site until there is suitable space provided to properly protect equipment from rust, drip, humidity, and dust damage.
- B. Capacities shall be not less than those indicated but shall be such that no component or system becomes inoperative or is damaged because of startup or other overload conditions.
- C. **Conformance with Agency Requirements:** Where materials or equipment are specified to be approved, listed, tested, or labeled by the Underwriters Laboratories, Inc., or constructed and/or tested in accordance with the standards of the American Society of Mechanical Engineers or the Air Moving and Conditioning Association, the Contractor shall submit proof that the items furnished under this section of the specifications conform to such requirements. The label of the Underwriters Laboratories, Inc., applied to the item will be acceptable as sufficient evidence that the items conform to such requirements. The ASME stamp or the AMCA label will be acceptable as sufficient evidence that the items conform to the respective requirements.
- D. **Nameplates:** Each major component of equipment shall have the manufacturer's name, address, and catalog number on a plate securely attached to the item of equipment. All data on nameplates shall be legible at the time of Final Inspection.
- E. **Protection from Moving Parts:** Belts, pulleys, shafts, chains, gears, couplings, projecting set screws, keys, and other rotating parts shall be fully enclosed or properly guarded for personnel protection.
- F. **Verification of Dimensions:** The Contractor shall be responsible for the coordination and proper relation of his work to the building structure and to the work of all trades. The Contractor shall visit the premises and become thoroughly familiar with all details of the work and working conditions, to verify all dimensions in the field, and to advise the Architect/Engineer of any discrepancy before performing any work. Adjustments to the work required in order to facilitate a coordinated installation shall be made at no additional cost to the Owner or the Architect/Engineer.

#### 1.12 MANUFACTURER'S RECOMMENDATIONS

- A. The manufacturer's published directions shall be followed in the delivery, storage, protection, installation, piping, and wiring of all equipment and material. The Contractor shall promptly notify the Architect/Engineer, in writing, of any conflict between the requirements of the Contract

Documents and the manufacturer's directions, and shall obtain the Architect/Engineer's instructions before proceeding with the work. Should the Contractor perform any such work that does not comply with the manufacturer's directions or such instructions from the Architect/Engineer, he shall bear all costs arising in connection with the deficiencies.

#### 1.13 SPACE AND EQUIPMENT ARRANGEMENT

- A. The size of mechanical and electrical equipment indicated on the drawings is based on the dimensions and performance of a particular manufacturer. While other manufacturers may be acceptable, it is the responsibility of the Contractor to determine if the equipment he proposes to furnish will fit in the space and can use the same electrical circuit and overcurrent protection. Fabrication drawings shall be prepared when required by the Architect/Engineer or Owner to indicate a suitable arrangement.
- B. All equipment shall be installed in a manner to permit access to all surfaces. All valves, motors, drives, filters, and other accessory items shall be installed in a position to allow removal for service without disassembly of another part.

#### 1.14 LARGE APPARATUS

- A. Any large piece of apparatus that is to be installed in any space in the building, and that is too large to permit access through stairways, doorways, or shafts shall be brought to the job and placed in the space before the enclosing structure is completed. Following placement in the space, such apparatus shall be thoroughly, completely protected from damage as hereinafter specified.

#### 1.15 PROTECTION

- A. The Contractor shall at all times take such precautions as may be necessary to properly protect all materials and equipment from damage from the time of delivery until the completion of the work, damaged equipment observed by the engineer or owner will be replaced with new equipment at no charge to the owner. This shall include the erection of all required temporary shelters and supports to adequately protect any items stored in the open on the site from the weather, the ground and surrounding work; the cribbing of any items above the floor of the construction; and the covering of items in the incomplete building with tarpaulins or other protective covering; the installation of electric heaters in electrical switchgear and similar equipment to prevent moisture damage. Failure on the part of the Contractor to comply with the above will be sufficient cause for the rejection of the items in question.
- B. Take particular care not to damage the building structure in performing work. All finished floors, step treads, and finished surfaces shall be covered to prevent any damage by workers or their tools and equipment during the construction of the building.
- C. Equipment and materials shall be protected from rust both before and after installation. Any equipment or materials found in a rusty condition at the time of final inspection must be cleaned of rust and repainted as specified elsewhere in these specifications.

#### 1.16 COOPERATION BETWEEN TRADES AND WITH OTHER CONTRACTORS

- A. Each trade, subcontractor, and/or Prime Contractor must work in harmony with the various other trades, subcontractors and/or Contractors on the job as may be required to facilitate the

progress to the best advantage of the job as a whole. Each trade, subcontractor, and/or Contractor must pursue its work promptly and carefully so as not to delay the general progress of the job. This Contractor shall work in harmony with Contractors working under other contracts on the premises. The overall project requirements of the construction documents are the responsibility of the Prime contractor. These documents do not imply who is responsible for the work and only that it must be performed by the prime contractor or one of the subcontractors under their prevue.

1.17 ELECTRICAL WIRING OF MOTORS AND EQUIPMENT

- A. The Contractor shall note that the electrical design and drawings are based on the equipment scheduled and indicated on the drawings, and should any mechanical equipment be provided requiring changes to the electrical design, the required electrical changes shall be made at no cost to the Owner.
- B. The electrical trades shall provide all interconnecting wiring for the installation of all power. The electrical trades shall provide all disconnect switches as required for proper operation, as indicated on the drawings or required by applicable code. All combination starters, individual starters, and other motor starting apparatus not specifically scheduled or specified as provided by the equipment manufacturer under the scope of Division 23, shall be provided under the scope of Division 26.
- C. The Mechanical Trades shall provide complete wiring diagrams indicating power wiring and interlock wiring. Diagrams shall be submitted to the Architect/Engineer for review within thirty (30) days after the submittals for equipment have been reviewed and approved. Diagrams shall be based on accepted equipment and shall be complete full phase and interlock control drawings, not a series of manufacturer's individual diagrams. After these diagrams have been reviewed by the Architect/Engineer, copies shall be transmitted to the electrical and controls trades by the Contractor. They shall be followed in detail.

1.18 SUPERVISION

- A. Each Contractor and subcontractor shall keep a competent superintendent or foreman on the job at all times.
- B. It shall be the responsibility of each superintendent to study all drawings and familiarize himself with the work to be done by other trades. He shall coordinate his work with other trades and before material is fabricated or installed, make sure that his work will not cause an interference with another trade. Where interferences are encountered, they shall be resolved at the job site by the superintendents involved. Where interferences cannot be resolved without major changes to the drawings, the matter shall be referred to the A/E for ruling.

1.19 SITE OBSERVATION

- A. Site observation by the Architect/Engineer is for the express purpose of verifying compliance by the Contractor with the Contract Documents, and shall not be construed as construction supervision nor indication of approval of the manner or location in which the work is being performed as being a safe practice or place. Nor as a code inspection.

1.20 PRECEDENCE OF MATERIALS

- A. The specifications determine the nature and setting of materials and equipment. The drawings establish quantities, dimensions and details.
- B. The installation precedence of materials shall be as follows. Note that if a interference is encountered, this shall guide the contractor in the determination of which trade shall be given the "Right-of-Way."
  - Building lines
  - Structural Members
  - Soil and Drain Piping
  - Condensate Drains
  - Vent Piping
  - Supply, Return, and Outside Air Ductwork
  - Exhaust Ductwork
  - HVAC Water and Steam Piping
  - Steam Condensate Piping
  - Fire Protection Piping
  - Natural Gas Piping
  - Domestic Water (Cold and Hot)
  - Refrigerant Piping
  - Electrical Conduit

1.21 CONNECTIONS FOR OTHERS

- A. The Mechanical Contractor shall rough in for and make all steam, hydronics, etc. connections to all fixtures, equipment, machinery, etc., provided by others in accordance with detailed roughing in drawings provided by the equipment suppliers, by actual measurements of the equipment connections, or as detailed.
- B. After the equipment is set in place, this Contractor shall make all final connections and shall provide all required pipe, fittings, valves, traps, etc.
- C. Provide all air gap fittings required, using materials hereinbefore specified. In each service line connected to an item of equipment or piece of machinery, provide a shutoff valve. On each drain not provided with a trap, provide a suitable trap.
- D. All pipe fittings, valves, traps, etc., exposed in finished areas and connected to chrome plated lines provided by others shall be chrome plated to match.
- E. Provide all sheet metal ductwork, transition pieces, etc., required for a complete installation of vent hoods, fume hoods, etc., provided by others.
- F. The piping contractor is also responsible for ensuring di-electric connections and materials are compatible.
- G. The piping contractor shall also make sure that all necessary equipment by-passes are in place for flushing and purging and be present for that process.
- H. The project is also responsible for ensuring all these connections are made prior to flushing and purging the hydronic systems.

## 1.22 INSTALLATION METHODS

- A. Where to Conceal: All pipes, conduits, etc., shall be concealed in pipe chases, walls, furred spaces, or above the ceilings of the building unless otherwise indicated.
- B. Where to Expose: In mechanical rooms, janitor's closets tight against pan soffits in exposed "Tee" structures, or storage spaces, but only where necessary, piping may be run exposed. All exposed piping shall be run in the most aesthetic, inconspicuous manner, and parallel or perpendicular to the building lines.
- C. Support: All piping, ducts and conduits shall be adequately and properly supported from the building structure by means of hanger rods or clamps to walls as herein specified.
- D. Maintaining Clearance: Where limited space is available above the ceilings below concrete beams or other deep projections, pipe and conduit shall be sleeved through the projection where it crosses, rather than hung below them in a manner to provide maximum above floor clearance. Sleeves shall be as herein specified. Approval shall be obtained from the Architect/Engineer for each penetration.
- E. All pipe, conduits, etc., shall be cut accurately to measurements established at the building and shall be worked into place without springing or forcing. All ducts, pipes and conduits run exposed in machinery and equipment rooms shall be installed parallel to the building lines, except that piping shall be sloped to obtain the proper pitch. Piping, ducts and conduits run in furred ceilings, etc., shall be similarly installed, except as otherwise shown. Conduits in furred ceilings and in other concealed spaces shall be neatly grouped and racked indicating good workmanship. All conduit and pipe openings shall be kept closed until the systems are closed with final connections.
  - 1. All piping not directly buried in the ground shall be considered as "interior piping." But if exposed to freezing conditions it must be heat traced.
  - 2. Prior to the installation of any ceiling material, gypsum, plaster, or acoustical board, the Contractor shall notify the construction inspector so that arrangement can be made for an inspection of the above ceiling area about to be "sealed" off. The Contractor shall give as much advance notice as possible no less than 10 working days. Access doors shall be installed as necessary for code or service access.
  - 3. All above ceiling areas will be subject to a formal inspection before ceiling panels are installed, or installation is otherwise concealed from view. All mechanical and electrical work at and above the ceiling, including items supported by the ceiling grid, such as air inlets or outlets and lighting fixtures, shall be complete and installed in accordance with contract requirements, including power to lighting fixtures, fans, and other powered items. Adequate lighting shall be provided to permit thorough inspection of all above ceiling items.
  - 4. The purpose of this inspection is to verify the completeness and quality of the installation of the air conditioning systems, the electrical systems, the plumbing systems, and any other special above ceiling systems such as vacuum systems, fire sprinkler piping and cable tray systems. The ceiling supports (tee bar or lath) shall be in place so that access panel and light fixture locations are identifiable and so that clearances and access provisions may be evaluated.

## 1.23 RECORDS FOR OWNER

- A. The Contractor shall maintain a set of "blue-line" prints in the Field Office for the sole purpose of recording "installed" conditions. Daily note all changes made in these drawings in connection

with the final installation including exact dimensioned locations of all new underground utilities, services and systems and all uncovered existing active and inactive piping outside the building.

- B. At contract completion, the contractor shall transfer the information from the "blueline" prints maintained as described above and turn over this neatly marked set of reproducible drawings representing the "as installed" work to the Architect/Engineers for verification and subsequent transmittal to the Owner. The Contractor shall refer to Division 01 of these specifications, for additional information. These drawings shall include as a minimum:
1. Addendum written drawing changes.
  2. Addendum supplementary drawings.
  3. Accurate, dimensioned locations of all underground utilities, services and systems.
  4. Identification of equipment work shown on Alternates as to whether alternates were accepted and work actually installed.
  5. Change Order written drawing changes.
  6. Change Order supplementary drawings.
- C. Electronic Media
1. In addition to the drawings described above in 1.25B, the contractor shall submit a set of discs containing all the drawings in AUTOCAD 2020 format or AUTOCAD Revit 2020 format. .
- D. "As installed" drawings shall bear a stamp, "stick-on decal" or lettered title block generally located in lower right hand corner of drawing entitled "AS INSTALLED DRAWING" with Company name of the installing trade Subcontractor and with a place for the date and the name of the responsible company representative.
- E. In addition to the above, the Contractor shall accumulate during the progress of the job the following data, in duplicate, prepared in a neat brochure or packet folder and turn over to the Architect/Engineer for review, and subsequent delivery to the Owner.
1. All warranties and guarantees and manufacturers' directions on equipment and material covered by the Contract.
  2. Two sets of operating instructions for heating and cooling and other mechanical and electrical systems. Operating instructions shall also include recommended preventative maintenance and seasonal changeover procedures.
  3. Valve tag charts and diagrams specified herein.
  4. Approved wiring diagrams and control diagrams representing "as installed" conditions.
  5. Copies of approved shop drawings.
  6. Any and all other data and/or drawings required as submittals during construction.
  7. Repair parts list of all major items and equipment including name, address and telephone number of local supplier or agent.
- F. All of the above data shall be submitted to the Architect/Engineer for approval and shall be corrected as instructed by the Architect/Engineer prior to submission of the final request for payment.

#### 1.24 CUTTING AND PATCHING

- A. General: Cut and patch walls, floors, etc., resulting from work in existing construction or by failure to provide proper openings or recesses in new construction.

- B. Methods of cutting: Openings cut through concrete and masonry shall be made with masonry saws and/or core drills and at such locations acceptable to the Architect/Engineer. Impact type equipment shall not be used except where specifically acceptable to the Architect/Engineer. Openings in precast concrete slabs for pipes, conduits, outlet boxes, etc., shall be core drilled to exact size.
- C. Restoration: All openings shall be restored to "as new" condition under the appropriate specification section for the materials involved and shall match remaining surrounding materials and/or finishes. Any penetrations shall be left with clean lines and cut edges that are no larger than 1" beyond the penetrating material.
- D. Masonry: Where openings are cut through masonry walls, provide and install lintels or other structural supports to protect the remaining masonry. Adequate supports shall be provided during the cutting operation to prevent any damage to the masonry occasioned by the operation. All structural members, supports, etc., shall be of the proper size and shape, and shall be installed in a manner acceptable to the Architect/Engineer. The restoration paragraph above also applies.
- E. Plaster: All mechanical work in areas containing plaster shall be completed prior to the application of the finish plaster coat. Cutting of finish plaster coat will not be permitted.
- F. Special Note: No cutting, boring, or excavating that will weaken the structure shall be undertaken.

#### 1.25 ROOF PENETRATIONS AND FLASHING

- A. Pipe, conduit and duct sleeves, pitch pockets, and flashings compatible with the roofing installation shall be provided and installed by a qualified contractor for all roof penetrations. This shall be the responsibility of the Prime Contractor.

#### 1.26 EXCAVATION, TRENCHING AND BACKFILL

- A. Excavation (See Divisions 01 for special requirements related to excavation and trenching.):
  - 1. The mechanical subcontractors or when acting as Prime contractor shall perform all excavations of every description, for their particular installations and of whatever substances encountered, to the depths indicated on the drawings and/or required for the installation of piping, or utility systems, etc. All exterior lines shall be installed with a minimum cover of 24" unless otherwise indicated on drawings. Generally, more cover shall be provided if grade will permit. All excavation materials not required for backfill or fill shall be removed and wasted as acceptable to the Construction Inspector. All excavations shall be made only by open cut. The banks of trenches shall be kept as nearly vertical as possible and where required, shall be properly sheeted and braced. Trenches shall be not less than 12" wider nor more than 16" wider than the outside edges of the pipe to be laid therein, and shall be excavated true to line so that a clear space not less than 6" nor more than 8" in width is provided on each side of the pipe. For sewers, the maximum width of trench specified applies to the width at and below the level of the pipe, and may be made as wide as necessary for sheeting and bracing and proper installation of the work. Thrust blocking shall be provided on all piping where an elbow is installed underground.
  - 2. The bottom of trenches shall be accurately graded to provide proper fall and uniform bearing and support for each section of the pipe on undisturbed soil or 6" of sand fill at every point along its entire length, except for portions of the pipe sections where it is

necessary to excavate for bell holes and for the proper sealing of pipe joints. Bell holes shall be dug after the trench bottom has been graded. Where inverts are not shown, grading shall be determined by the National Plumbing Code for the service intended and the size used. Bell holes for lead pipe joints shall be 12" in depth below the trench bottom and shall extend from a point 6" back of the face of the bell. Such bell holes shall be of sufficient width to provide ample room for caulking. Bell holes for sewer tile and water pipe shall be excavated only to an extent sufficient to permit accurate work in the making of the joints and to insure that the pipe, for a maximum of its length, will rest upon the prepared bottom of the trench. Depressions for joints other than bell-and-spigot shall be made in accordance with the recommendations of the joint manufacturer for the particular type of joint used. In general, grading for electrical ductbanks and conduits shall be from building to manhole, and from a high point between manholes to each manhole. Special pipe beds shall be provided as specified hereinafter.

3. The lower 4" of the pipe trenches measuring from an overhead line set parallel to the grade line of the sewer shall be excavated only a few feet in advance to the pipe laying, by workers especially skilled in this type of work. Where damage is likely to result from withdrawing sheeting, the sheeting shall be left in place. Except at locations where excavation of rock from the bottom of trenches is required, care shall be taken not to excavate below the depths required. Where rock excavation is required, the rock shall be excavated to a minimum overdepth of 6" below the trench depths specified. The overdepth rock excavation and all excess trench excavation shall be backfilled with sand. Whenever wet or otherwise unstable soil is incapable of properly supporting the pipe is encountered in the trench bottom, such soil shall be removed to a depth and for the trench lengths required, and then backfilled to trench bottom grade, as hereinafter specified, with sand.
4. All grading in the vicinity of excavation shall be controlled to prevent surface ground water from flowing into the excavations. Any water accumulated in the excavations shall be removed by pumping or other acceptable method. During excavation, material suitable for backfilling shall be stacked in an orderly manner a sufficient distance back from edges of trenches to avoid overloading and prevent slides or cave-ins.
5. All shoring and sheeting required to perform and protect the excavations and to safeguard employees and/or adjacent structures shall be provided by the contractor doing the work. .
6. Excavate as required under the building in order that all piping, ductwork, etc., shall clear the ground a minimum of 12" for a distance of 24" on either side. Edges of such excavations shall slope at an angle of not over 45 degrees with the horizontal.
7. Trenches for cast iron drain, storm water and sewer lines inside the building shall be properly excavated, following, in general, the procedures set out for exterior lines. Where floors are to be poured over these lines, they shall be backfilled, tamped and settled with water. Where no flooring is to cover the lines, they shall be backfilled to form a level grade.
8. All surplus materials removed in these trenching operations becomes the property of the contractor and shall be disposed of at the expense of the contractor, at a legal disposal site. Testing required by disposal site shall be paid for by the contractor.

#### B. Backfilling

1. Trenches shall not be backfilled until all required tests are performed and until the piping, utilities systems, etc., as installed are certified by the to conform to the requirements specified hereinafter. The trenches shall be carefully backfilled with sand to a depth of 12 inches above the top of the pipe. The next layer and subsequent layers of backfill may be excavated materials approved for backfilling, consisting of earth, loam, sandy clay, sand and gravel, soft shale, or other approved materials free from large clods of earth or stones larger than 1 1/2" in diameter, flooded until the pipe has cover of not less than one foot. The remainder of the backfill material shall then be thrown into the trenches, moistened, and tamped or flooded in one-foot layers. Blasted rock, broken concrete or

- pavement, and large boulders shall not be used as backfill material. Any trenches improperly backfilled, or where settlement occurs, shall be reopened to the depth required for proper compaction, then refilled and mounded over, and smoothed off.
2. Backfill under concrete slabs-on-fill shall be as specified above, shall be gravel, or shall be other such materials more suitable for the application. Installation and compaction shall be as required for compatibility with adjacent materials.
- C. Opening and Re-closing Pavement and Lawns: Where excavation requires the opening of existing walks, streets, drives, other existing pavement, or lawns, such surfaces shall be cut as required to install new lines and to make new connections to existing lines. The sizes of the cut shall be held to a minimum, consistent with the work to be accomplished. After the installation of the new work is completed and the excavation has been backfilled and flooded, the area shall be patched, using materials to match those cut out. The patches shall thoroughly bond with the original surfaces and shall be level with them and shall meet all the requirements established by the authorities having jurisdiction over such areas.
- 1.27 ACCESS DOORS
- A. General: This Contractor shall provide wall or ceiling access doors for unrestricted access to all concealed items of mechanical equipment or devices.
- B. Doors: Access doors mounted in painted surfaces shall be of Milcor (Inland-Ryerson Construction Products Company) manufacture, Style K for plastered surfaces and Style M or DW for non-plastered surfaces. The Style K doors shall be set so that the finished surface of the door is even with the finished surface of the adjacent finishes. Access doors mounted on tile surfaces shall be of similar construction as noted above, except they shall be of stainless steel materials. Access doors shall be a minimum of 12" x 12" in size and be labeled with item name of the device for which they provide access.
- 1.28 OPERATION PRIOR TO COMPLETION
- A. When any piece of mechanical equipment is operable and it is to the advantage of the Contractor to operate the equipment, he may do so, providing that he properly supervises the operation. The warranty period shall, however, not commence until the equipment is operated for the beneficial use of the Owners occupants, or date of substantial completion, whichever occurs first. Proper air filtering must be provided in accordance with LEED requirements whether being certified or not. All duct openings during construction must also be protected under the same LEED requirements whether being certified or not.
- B. Regardless of whether or not the equipment has or has not been operated, the Contractor shall properly clean the equipment, install clean filter media, properly adjust, and complete all deficiency list items before final acceptance by the Owner. The date of acceptance and performance certification will be the same date.
- 1.29 EXISTING BUILDINGS (To Engineer: Remove this section when not required).
- A. The Contractor shall be responsible for loss or damage to the existing facilities caused by him and his workers and shall be responsible for repairing or replacing such loss or damage. The Contractor shall send proper notices, make necessary arrangements, and perform other services required for the care, protection and in-service maintenance of all plumbing, heating, air conditioning, and ventilating services for the new and existing facilities. The Contractor shall

erect temporary barricades, with necessary safety devices, as required to protect personnel from injury, removing all such temporary protection upon completion of the work.

- B. The Contractor shall provide temporary or new services to all existing facilities as required to maintain their proper operation when normal services are disrupted as a result of the work being accomplished under this project.
- C. Where existing construction is removed to provide working and extension access to existing utilities, Contractor shall remove doors, piping, conduit, outlet boxes, wiring, light fixtures, air conditioning ductwork and equipment, etc., to provide this access and shall reinstall them upon completion of work in the areas affected.
- D. Where partitions, walls, floors, or ceilings of existing construction are indicated to be removed, all Contractors shall remove and reinstall in locations approved by the Architect/Engineer all devices required for the operation of the various systems installed in the existing construction. This is to include but is not limited to temperature controls system devices, electrical switches, relays, fixtures, piping, conduit, etc.
- E. Outages of services as required by the new installation will be permitted but only at a time approved by the Owner. The Contractor shall allow the Owner two weeks in order to schedule required outages. The time allowed for outages will not be during normal working hours unless otherwise approved by the Owner. All costs of outages, including overtime charges, shall be included in the contract amount.

#### 1.30 DEMOLITION AND RELOCATION

- A. The Contractor shall modify, remove, and/or relocate all materials and items so indicated on the drawings. Materials and/or items scheduled for relocation and which are damaged during dismantling or reassembly operations shall be repaired and restored to good operative condition. The Contractor may, at his discretion, and upon the approval of the Owner, substitute new materials and/or items of like design and quality in lieu of materials and/or items to be relocated.
- B. All items that are to be relocated shall be carefully removed in reverse to original assembly or placement and protected until relocated. The Contractor shall clean and repair and provide all new materials, fittings, and appurtenances required to complete the relocations and to restore to good operative order. All relocations shall be performed by workers skilled in the work and in accordance with standard practice of the trades involved.
- C. When items scheduled for relocation and/or reuse are found to be in damaged condition before work has been started on dismantling, the Contractor shall call the attention of the Owner to such items and receive further instructions before removal. Items damaged in repositioning operations are the Contractor's responsibility and shall be repaired or replaced by the Contractor as approved by the Owner, at no additional cost to the Owner.
- D. Service lines and wiring to items to be removed, salvaged, or relocated shall be removed to points indicated on the drawings, specified, or acceptable to the Owner. Service lines and wiring not scheduled for reuse shall be removed to the points at which reuse is to be continued or service is to remain. Such services shall be sealed, capped, or otherwise tied off or disconnected in a safe manner acceptable to the Owner. All disconnections or connections into the existing facilities shall be done in such a manner as to result in minimum interruption of services to adjacent occupied areas. Services to existing areas or facilities that must remain in operation during the construction period shall not be interrupted without prior specific approval of the Owner as hereinbefore specified.

### 1.31 TESTS

- A. The Contractor shall make, at no additional cost to the Owner, any tests deemed necessary by the inspection departments having jurisdiction, and in the National Fire Protection Association, ASTM, etc. Standards listed. The Contractor shall provide all equipment, materials, and labor for making such tests. Reasonable amounts of fuel and electrical energy costs for system tests will be paid by the Owner. Fuel and electrical energy costs for system adjustment and tests that follow beneficial occupancy by the Owner will be borne by the Owner.
- B. Additional tests specified hereinafter under the various specification sections shall be made by the contractor at no additional cost to the owner. .
- C. Maintain Log of Tests as hereinafter specified.
- D. See specifications hereinafter for additional tests and requirements.
- E. Reports from flushing contractor on flow and pressure shall also be provided as part of the testing of piping systems.

### 1.32 COOPERATION AND CLEANUP

- A. It shall be the responsibility of each trade to cooperate fully with the other trades on the job to help keep the job site in a clean and safe condition. At the end of each day's work, each trade shall properly store all of his tools, equipment and materials and shall clean his debris from the job. Upon the completion of the job, each trade shall immediately remove all of his tools, equipment, any surplus materials and all debris caused by that portion of the work. Contractor is responsible for any loss of materials or tools during their scope of work.

### 1.33 PAINTING

- A. Scope of painting for Divisions 23 --work in areas other than those defined as "exposed" is as follows:
  - 1. All uncovered steel pipe, supports, exposed pipe and hanger rod threads, and hangers in underfloor spaces shall be cleaned and painted with two coats of Tropical Paint Co. No. 77-black asphaltic emulsion. Galvanized steel and copper lines in these spaces shall not be painted.
  - 2. All canvas finishes including those underfloor and in concealed spaces shall be painted with one sizing coat if not already sized, containing mildew resistant additive and Arabol adhesive prior to any other specified finish paint.
  - 3. If insulated, the piping shall be primed, only, prior to insulation, and the insulation jacketing shall be painted as specified for piping. The requirements of this paragraph are "primary" and have priority over any conflicting specification or instruction, should a conflict in the Construction Documents exist.
- B. The surfaces to be finish painted shall first be prepared as follows:
  - 1. Galvanized and black steel surfaces shall first be painted with one (1) coat of P&L galvanized metal primer.
  - 2. Cast iron pipe shall first be primed with a "non-bleed" primer.

- C. All ferrous metal surfaces without a protective finish and not galvanized in exposed and concealed areas including chases, underfloor and above ceilings shall be painted with two (2) coats of P&L zinc chromate primer as the construction progresses to protect against deterioration.

**PART 2 - PRODUCTS**

1.34 Not Used.

**PART 3 - EXECUTION**

1.35 PIPE PRESSURE TESTS

- A. The following lines shall be tested at the stated pressure for the length of time noted:

<u>Testing Service</u>	<u>Testing Medium</u>	<u>Pressure (PSIG)</u>	<u>Hours</u>	<u>Time in</u>
Chilled Water / Heating	Water	150		24
Hot Water				
Steam M.P. & L.P.	Water	150		24
Steam Condensate M.P.	Water	150		24
Steam H.P.	Water	300	24	
Steam Condensate H.P.	Water	300		24
Pumped Condensate Return	Water	150	24	

- B. Where leaks occur, the pipe shall be repaired, and the tests repeated. No leaks shall be corrected by peening. Defective piping and joints shall be removed and replaced.
- C. Flushing and purging shall be done upon completion of these tests and any failures including leaks shall be repaired and retesting as stated above to be repeated including flushing and purging.

END OF SECTION 23 00 00

## **SECTION 23 01 30.51 - HVAC AIR-DISTRIBUTION SYSTEM CLEANING**

### **PART 1 - GENERAL**

#### 1.1 SUMMARY

- A. Section includes cleaning HVAC air-distribution equipment, ducts, plenums, and system components.

#### 1.2 DEFINITIONS

- A. ASCS: Air systems cleaning specialist.
- B. NADCA: National Air Duct Cleaners Association.

#### 1.3 SUBMITTALS

- A. Qualification Data: For an ASCS.
- B. Strategies and procedures plan.
- C. Cleanliness verification report.

#### 1.4 QUALITY ASSURANCE

- A. ASCS Qualifications: A certified member of NADCA.
  - 1. Certification: Employ an ASCS certified by NADCA on a full-time basis.
  - 2. Supervisor Qualifications: Certified as an ASCS by NADCA.
- B. UL Compliance: Comply with UL 181 and UL 181A for fibrous-glass ducts.
- C. Cleaning Conference: Conduct conference at Project site.
  - 1. Review methods and procedures related to HVAC air-distribution system cleaning including, but not limited to, review of the cleaning strategies and procedures plan.

### **PART 2 - PRODUCTS (Not Used)**

### **PART 3 - EXECUTION**

#### 3.1 EXAMINATION

- A. Examine HVAC air-distribution equipment, ducts, plenums (including under stage floor), and system components to determine appropriate methods, tools, and equipment required for performance of the Work.

- B. Perform "Project Evaluation and Recommendation" according to NADCA ACR 2006.
- C. Prepare written report listing conditions detrimental to performance of the Work.
- D. Proceed with work only after unsatisfactory conditions have been corrected.

### 3.2 PREPARATION

- A. Prepare a written plan that includes strategies and step-by-step procedures. At a minimum, include the following:
  - 1. Supervisor contact information.
  - 2. Work schedule including location, times, and impact on occupied areas.
  - 3. Methods and materials planned for each HVAC component type.
  - 4. Required support from other trades.
  - 5. Equipment and material storage requirements.
  - 6. Exhaust equipment setup locations.
- B. Use the existing service openings, as required for proper cleaning, at various points of the HVAC system for physical and mechanical entry and for inspection.
- C. Comply with NADCA ACR 2006, "Guidelines for Constructing Service Openings in HVAC Systems" Section.

### 3.3 CLEANING

- A. Comply with NADCA ACR 2006.
- B. Remove visible surface contaminants and deposits from within the HVAC system.
- C. Systems and Components to Be Cleaned:
  - 1. Air devices for supply and return air.
  - 2. Air-terminal units.
  - 3. Ductwork:
    - a. Supply-air ducts, including turning vanes and reheat coils, to the air-handling unit.
    - b. Return-air ducts to the air-handling unit.
    - c. Exhaust-air ducts.
    - d. Underfloor plenum areas
  - 4. Air-Handling Units (roof top or inside the building):
    - a. Interior surfaces of the unit casing.
    - b. Coil surfaces compartment.
    - c. Condensate drain pans.
    - d. Fans, fan blades, and fan housings.
  - 5. Filters and filter housing.
- D. Collect debris removed during cleaning. Ensure that debris is not dispersed outside the HVAC system during the cleaning process.

- E. Particulate Collection:
  - 1. For particulate collection equipment, adequate filtration to contain debris removed. Locate equipment downwind and away from all air intake and other points of entry into the building.
  - 2. HEPA filtration with 99.97 percent collection efficiency for particles sized 0.3 micrometer or larger shall be used where the particulate collection equipment is exhausting inside the building,
- F. Control odors and mist vapors during the cleaning and restoration process.
- G. Mark the position of manual volume dampers and air-directional mechanical devices inside the system prior to cleaning. Restore them to their marked position on completion of cleaning.
- H. System components shall be cleaned so that all HVAC system components are visibly clean. On completion, all components must be returned to those settings recorded just prior to cleaning operations.
- I. Clean all air-distribution devices, registers, grilles, and diffusers.
- J. Clean visible surface contamination deposits according to NADCA ACR 2006 and the following:
  - 1. Clean air-handling units, airstream surfaces, components, condensate collectors, and drains.
  - 2. Ensure that a suitable operative drainage system is in place prior to beginning wash-down procedures.
  - 3. Clean evaporator coils, reheat coils, and other airstream components.
- K. Duct Systems:
  - 1. Create service openings in the HVAC system as necessary to accommodate cleaning.
  - 2. Mechanically clean duct systems are specified to remove all visible contaminants so that the systems are capable of passing the HVAC System Cleanliness Tests (see NADCA ACR 2006).
- L. Debris removed from the HVAC system shall be disposed of according to applicable Federal, state, and local requirements.
- M. Mechanical Cleaning Methodology:
  - 1. Source-Removal Cleaning Methods: The HVAC system shall be cleaned using source-removal mechanical cleaning methods designed to extract contaminants from within the HVAC system and to safely remove these contaminants from the facility. No cleaning method, or combination of methods, shall be used that could potentially damage components of the HVAC system or negatively alter the integrity of the system.
    - a. Use continuously operating vacuum-collection devices to keep each section being cleaned under negative pressure.
    - b. Cleaning methods that require mechanical agitation devices to dislodge debris that is adhered to interior surfaces of HVAC system components shall be equipped to safely remove these devices. Cleaning methods shall not damage the integrity of HVAC system components or damage porous surface materials such as duct and plenum liners.
  - 2. Cleaning Mineral-Fiber Insulation Components:

- a. Fibrous-glass thermal or acoustical insulation elements present in equipment or ductwork shall be thoroughly cleaned with HEPA vacuuming equipment while the HVAC system is under constant negative pressure and shall not be permitted to get wet according to NADCA ACR 2006.
- b. Cleaning methods used shall not cause damage to fibrous-glass components and will render the system capable of passing the HVAC System Cleanliness Tests (see NADCA ACR 2006).
- c. Fibrous materials that become wet shall be discarded and replaced.

N. Coil Cleaning:

1. Measure static-pressure differential across each coil.
2. See NADCA ACR 2006, "Coil Surface Cleaning" Section. Type 1, or Type 1 and Type 2, cleaning methods shall be used to render the coil visibly clean and capable of passing Coil Cleaning Verification (see applicable NADCA ACR 2006).
3. Coil drain pans shall be subject to NADCA ACR 2006, "Non-Porous Surfaces Cleaning Verification." Ensure that condensate drain pans are operational.
4. Electric-resistance coils shall be de-energized, locked out, and tagged before cleaning.
5. Cleaning methods shall not cause any appreciable damage to, cause displacement of, inhibit heat transfer, or cause erosion of the coil surface or fins, and shall comply with coil manufacturer's written recommendations when available.
6. Rinse thoroughly with clean water to remove any latent residues.

O. Antimicrobial Agents and Coatings:

1. Apply antimicrobial agents and coatings if active fungal growth is reasonably suspected or where unacceptable levels of fungal contamination have been verified. Apply antimicrobial agents and coatings according to manufacturer's written recommendations and EPA registration listing after the removal of surface deposits and debris.
2. When used, antimicrobial treatments and coatings shall be applied after the system is rendered clean.
3. Apply antimicrobial agents and coatings directly onto surfaces of interior ductwork.
4. Sanitizing agent products shall be registered by the EPA as specifically intended for use in HVAC systems and ductwork.

### 3.4 CLEANLINESS VERIFICATION

- A. Verify cleanliness according to NADCA ACR 2006, "Verification of HVAC System Cleanliness" Section.
- B. Verify HVAC system cleanliness after mechanical cleaning and before applying any treatment or introducing any treatment-related substance to the HVAC system, including biocidal agents and coatings.
- C. Perform visual inspection for cleanliness. If no contaminants are evident through visual inspection, the HVAC system shall be considered clean. If visible contaminants are evident through visual inspection, those portions of the system where contaminants are visible shall be re-cleaned and subjected to re-inspection for cleanliness.
- D. Additional Verification:
  1. Perform surface comparison testing or NADCA vacuum test.
  2. Conduct NADCA vacuum gravimetric test analysis for nonporous surfaces.

- E. Verification of Coil Cleaning:
  - 1. Measure static-pressure differential across each coil.
  - 2. Coil will be considered clean if cleaning restored the coil static-pressure differential within 10 percent of static pressure scheduled, the differential measured when the coil was first installed.
  - 3. Coil will be considered clean if the coil is free of foreign matter and chemical residue, based on a thorough visual inspection.
  
- F. Prepare a written cleanliness verification report. At a minimum, include the following:
  - 1. Written documentation of the success of the cleaning.
  - 2. Site inspection reports, initialed by supervisor, including notation on areas of inspection, as verified through visual inspection.
  - 3. Surface comparison test results if required.
  - 4. Gravimetric analysis (nonporous surfaces only).
  - 5. System areas found to be damaged.
  
- G. Photographic Documentation: Comply with requirements in Division 01 Section "Photographic Documentation."

### 3.5 RESTORATION

- A. Restore and repair HVAC air-distribution equipment, ducts, plenums, and components according to NADCA ACR 2006, "Restoration and Repair of Mechanical Systems" Section.
- B. Restore service openings capable of future reopening. Comply with requirements in Division 23 Section "Metal Ducts." Include location of service openings in Project closeout report.
- C. Replace fibrous-glass materials that cannot be restored by cleaning or resurfacing. Comply with requirements in Division 23 Sections "Metal Ducts" and "Nonmetal Ducts."
- D. Replace damaged insulation according to "Division 23 Section "HVAC Insulation."
- E. Ensure that closures do not hinder or alter airflow.
- F. New closure materials, including insulation, shall match opened materials and shall have removable closure panels fitted with gaskets and fasteners.
- G. Reseal fibrous-glass ducts. Comply with requirements in Division 23 Section "Nonmetal Ducts."

**END OF SECTION**

## SECTION 23 05 13 - MOTORS

### PART 1 - GENERAL

#### 1.1 SUMMARY

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

#### 1.2 SUBMITTALS

- A. Specification Compliance: An electronic copy of the specification will be provided to vendors for their responses. Each vendor shall indicate one of the following on every specification requirement paragraph-by-paragraph:
  - 1. Comply - vendor complies or exceeds this requirement.
  - 2. Deviation - vendor deviated from this requirement, but provides similar operational and functional capability. Vendor to describe the deviation and how its product meets the specification performance requirement.
  - 3. Non-Compliant - vendor's proposed product does not meet the specification requirement.
- B. Product Data for Motors: For each type and size of motor, provide nameplate data and ratings; shipping, installed, and operating weights; enclosure type and mounting arrangements; size, type, and location of winding terminations; conduit entry and ground lug locations; and information on coatings or finishes.

#### 1.3 QUALITY ASSURANCE

- A. Source Limitations: Obtain motors through one source from a single manufacturer.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. Comply with NFPA 70.

#### 1.4 COORDINATION

- A. Coordinate features of motors, installed units, and accessory devices and features that comply with the following:
  - 1. Compatible with the following:
    - a. Magnetic controllers.
    - b. Multispeed controllers.
    - c. Reduced-voltage controllers
    - d. Variable frequency drives.

2. Designed and labeled for use with variable frequency controllers, and suitable for use throughout speed range without overheating.
  3. Matched to torque and horsepower requirements of the load.
  4. Matched to ratings and characteristics of supply circuit and required control sequence.
  5. Ambient and environmental conditions of installation location.
- B. Coordinate motor support with requirements for driven load; access for maintenance and motor replacement; installation of accessories, belts, belt guards; and adjustment of sliding rails for belt tensioning.
- C. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases.

## **PART 2 - PRODUCTS**

### 2.1 MANUFACTURERS

- A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified below.
    - a. Baldor
    - b. General Electric
    - c. Reliance
    - d. US Motor
    - e. Marathon
    - f. WEG

### 2.2 MOTOR REQUIREMENTS

- A. Motor requirements apply to factory- and field-installed motors except as follows:
1. Different ratings, performance, or characteristics for motor are specified in another Section.
  2. Motorized-equipment manufacturer requires ratings, performance, or characteristics, other than those specified in this Section, to meet performance specified.

### 2.3 MOTOR CHARACTERISTICS

- A. Motors 3/4 HP and Larger: Single Phase and Three phase.
- B. Frequency Rating: 60 Hz.
- C. Voltage Rating: NEMA standard voltage selected to operate on nominal circuit voltage to which motor is connected.
- D. Service Factor: 1.15 for open drip-proof motors; 1.15 for totally enclosed motors.
- E. Duty: Continuous duty at ambient temperature of 105 deg F I.

- F. 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.

## 2.4 POLYPHASE MOTORS

- A. Description: NEMA MG 1, Design B, medium induction motor.
- B. Efficiency: Premium, as defined in NEMA MG 1.
- C. Stator: Copper windings, unless otherwise indicated.
  - 1. Multispeed motors shall have separate winding for each speed.
- D. Rotor: Squirrel cage, unless otherwise indicated.
- E. Bearings: Double-shielded, pre-lubricated ball bearings suitable for radial and thrust loading.
- F. Temperature Rise: Match insulation rating, unless otherwise indicated.
- G. Insulation: Class F, unless otherwise indicated.
- H. Code Letter Designation:
  - 1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
  - 2. Motors Smaller Than 15 HP: Manufacturer's standard starting characteristic.
- I. Enclosure: Rolled steel for motors smaller than 75 hp. Unless specified elsewhere in this Division, provide motor enclosure types based on application as follows:
  - 1. Totally Enclosed Fan Cooled:
    - a. Pumps
    - b. Outdoor locations
    - c. Draw-through AHUs
    - d. Outside Air Handlings and Energy Recovery Units
    - e. All exhaust systems other than General Exhaust
  - 2. Totally Enclosed Air Over
    - a. Direct drive fan assemblies only
    - b. All exhaust systems other than General Exhaust with direct drive fan assemblies
  - 3. Open Drip Proof motors may only be used on the following with no exceptions:
    - a. Blow through AHUs with pretreated outside air
    - b. General exhaust
- J. Finish: Enamel in factory standard color.

## 2.5 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

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

- B. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.
  - 1. Designed with critical vibration frequencies outside operating range of controller output.
  - 2. Temperature Rise: Matched to rating for Class B insulation.
  - 3. Insulation: Class H and in accordance with NEMA MG1 Part 31 Standards.
  - 4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.
  - 5. For motors 1 hp and larger: Provide motor shaft grounding.
  - 6. For motors 100 hp and larger: Provide insulated bearings in addition to motor shaft grounding.
  
- C. Motors Used with Electrical Commutated Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.
  - 1. Designed with critical vibration frequencies outside operating range of controller output.
  - 2. Temperature Rise: Matched to rating for Class B insulation.
  - 3. Insulation: Class H and in accordance with NEMA MG1 Part 31 Standards.
  - 4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.
  - 5. For motors 1 hp and larger: Provide motor shaft grounding.
  
- D. Rugged-Duty Motors: Totally enclosed, with 1.25 minimum service factor, greased bearings, integral condensate drains, and capped relief vents. Windings insulated with non-hygroscopic material.
  - 1. Finish: Chemical-resistant paint over corrosion-resistant primer.
  
- E. Source Quality Control for Field-Installed Motors: Perform the following tests on each motor according to NEMA MG 1:
  - 1. Measure winding resistance.
  - 2. Read no-load current and speed at rated voltage and frequency.
  - 3. Measure locked rotor current at rated frequency.
  - 4. Perform high-potential test.

### **PART 3 - EXECUTION**

- 3.1 Not Applicable.

**END OF SECTION 23 05 13**

## SECTION 23 05 29 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

### PART 1 - GENERAL

#### 1.1 SUMMARY

A. Section Includes:

1. Trapeze pipe and duct hangers.
2. Metal framing systems.
3. Fastener systems.
4. Pipe stands.
5. Equipment supports.

B. Related Sections:

1. Division 05 Section "Metal Fabrications" for structural-steel shapes and plates for trapeze hangers for pipe and equipment supports.
2. Division 23 Section "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
3. Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for vibration isolation devices.
4. Division 23 Section(s) "Metal Ducts" and "Nonmetal Ducts" for duct hangers and supports.

#### 1.2 DEFINITIONS

- A. MSS: Manufacturers Standardization Society of The Valve and Fittings Industry Inc.

#### 1.3 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design trapeze pipe hangers and equipment supports, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

- B. Structural Performance: Hangers and supports for HVAC piping and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.

1. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.
2. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
3. Rooftop piping shall be shown to be anchored for the wind speed of the project as shown on the drawings.

#### 1.4 SUBMITTALS

- A. Product Data: For each type of product indicated.

- B. Shop Drawings: Show fabrication and installation details and include calculations for the following; include Product Data for components:
  - 1. Trapeze pipe and duct hangers.
  - 2. Metal framing systems.
  - 3. Pipe stands.
  - 4. Equipment supports other than housekeeping pads.
- C. Delegated-Design Submittal: For trapeze hangers 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 trapeze hangers.
  - 2. Design Calculations: Calculate requirements for designing trapeze hangers.
- D. Welding certificates.

#### 1.5 QUALITY ASSURANCE

- A. Structural Steel Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

### **PART 2 - PRODUCTS**

#### 2.1 METAL PIPE AND DUCT HANGERS AND SUPPORTS

- A. Carbon-Steel, Stainless Steel & Copper Pipe Hangers and Supports:
  - 1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
  - 2. Galvanized Metallic Coatings: Pregalvanized or hot dipped.
  - 3. Nonmetallic Coatings: Plastic coating, jacket, or liner.
  - 4. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
  - 5. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel.

#### 2.2 TRAPEZE PIPE HANGERS

- A. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural carbon-steel shapes with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.

#### 2.3 METAL FRAMING SYSTEMS

- A. MFMA Manufacturer Metal Framing Systems:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - a. Cooper B-Line, Inc.
  - b. Flex-Strut Inc.
  - c. GS Metals Corp.
  - d. Thomas & Betts Corporation.
  - e. Unistrut Corporation; Tyco International, Ltd.
  - f. HILTI
2. Description: Shop- or field-fabricated pipe-support assembly for supporting multiple parallel pipes.
3. Standard: MFMA-4.
4. Channels: Continuous slotted steel channel with in-turned lips.
5. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
6. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel.
7. Metallic Coating: Hot-dipped galvanized.

## 2.4 FASTENER SYSTEMS

- A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
- B. Mechanical-Expansion Anchors: Insert-wedge-type, zinc-coated steel anchors, for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

## 2.5 PIPE STANDS

- A. General Requirements for Pipe Stands: Shop- or field-fabricated assemblies made of manufactured corrosion-resistant components to support roof-mounted piping.
- B. Compact Pipe Stand: One-piece plastic unit with integral-rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.
- C. High-Type, Single-Pipe Stand:
  1. Description: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.
  2. Base: Plastic.
  3. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
  4. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with stainless-steel, roller-type pipe support.
- D. High-Type, Multiple-Pipe Stand:
  1. Description: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.
  2. Bases: One or more; plastic.
  3. Vertical Members: Two or more protective-coated-steel channels.
  4. Horizontal Member: Protective-coated-steel channel.

5. Pipe Supports: Galvanized-steel, clevis-type pipe hangers.

E. Curb-Mounted-Type Pipe Stands: Shop- or field-fabricated pipe supports made from structural-steel shapes, continuous-thread rods, and rollers, for mounting on permanent stationary roof curb.

## 2.6 EQUIPMENT SUPPORTS

A. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes such as angle iron or box channel. These supports are then protectively coated.

B. Roof curb adapters shall be design and installed to withstand the wind speeds of the project as shown on the drawing.

## 2.7 MISCELLANEOUS MATERIALS

A. Structural Steel: ASTM A 36/A 36M, carbon-steel plates, shapes, and bars; black and galvanized.

B. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.

1. Properties: Non-staining, noncorrosive, and nongaseous.
2. Design Mix: 5000-psi, 28-day compressive strength.

## PART 3 - EXECUTION

### 3.1 HANGER AND SUPPORT INSTALLATION

A. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.

1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.
2. Field fabricate from ASTM A 36/A 36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.

B. Metal Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled metal framing systems.

C. Fastener System Installation:

1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

- D. Pipe Stand Installation:
  - 1. Pipe Stand Types except Curb-Mounted Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.
  - 2. Curb-Mounted-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. See Division 07 Section "Roof Accessories" for curbs.
- E. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.
- F. Equipment Support Installation: Fabricate from welded-structural-steel shapes.
- G. Install hangers and supports to allow controlled thermal movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.
- H. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:
  - 1. NPS 3/4: Maximum span, 5 feet; minimum rod size, 1/4 inch.
  - 2. NPS 1: Maximum span, 6 feet; minimum rod size, 1/4 inch.
  - 3. NPS 1-1/2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
  - 4. NPS 2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
  - 5. NPS 2-1/2: Maximum span, 9 feet; minimum rod size, 3/8 inch.
  - 6. NPS 3: Maximum span, 10 feet; minimum rod size, 3/8 inch.
- I. Support vertical runs at roof, at each floor, and at 10-foot (3-m) intervals between floors.
- J. Install lateral bracing with pipe hangers and supports to prevent swaying.
- K. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.
- L. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
- M. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.
- N. Insulated Piping:
  - 1. Attach clamps and spacers to piping.
    - a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
    - b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
    - c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
  - 2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.

- a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
  - a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
4. Shield Dimensions for Pipe: Not less than the following:
  - a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.06 inch thick.
  - b. NPS 4: 12 inches long and 0.105 inch thick.
  - c. NPS 5 and NPS 6: 18 inches long and 0.105 inch thick.
  - d. NPS 8 to NPS 14: 24 inches long and 0.105 inch thick.
  - e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.
5. Pipes NPS 8 and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.
6. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

### 3.2 EQUIPMENT SUPPORTS

- A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.
- B. Grouting: Place grout under supports for equipment and make bearing surface smooth.
- C. Provide lateral bracing, to prevent swaying, for equipment supports.

### 3.3 METAL FABRICATIONS

- A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.
- B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.
- C. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:
  1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
  2. Obtain fusion without undercut or overlap.
  3. Remove welding flux immediately.
  4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

### 3.4 ADJUSTING

- A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.
- B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches.

### 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 a minimum dry film thickness of 2.0 mils.
- B. Touchup: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in Division 09
- C. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

### 3.6 HANGER AND SUPPORT SCHEDULE

- A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.
- B. Comply with MSS SP-69 for pipe-hanger selections and applications that are not specified in piping system Sections.
- C. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish.
- D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.
- E. Use carbon-steel pipe hangers and supports metal, trapeze pipe hangers and metal framing systems and attachments for general service applications.
- F. Use stainless-steel pipe hangers and stainless-steel attachments for hostile environment applications.
- G. Use copper-plated pipe hangers and copper attachments for copper piping and tubing.
- H. Use padded hangers for piping that is subject to scratching.
- I. Use thermal-hanger shield inserts for insulated piping and tubing.
- J. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
  - 1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of non-insulated or insulated, stationary pipes NPS 1/2 to NPS 30.
  - 2. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of up to 1050 deg F, pipes NPS 4 to NPS 24, requiring up to 4 inches of insulation.

3. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes NPS 3/4 to NPS 36, requiring clamp flexibility and up to 4 inches of insulation.
  4. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes NPS 1/2 to NPS 24 if little or no insulation is required.
  5. Pipe Hangers (MSS Type 5): For suspension of pipes NPS 1/2 to NPS 4, to allow off-center closure for hanger installation before pipe erection.
  6. Adjustable, Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of non-insulated, stationary pipes NPS 3/4 to NPS 8.
  7. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8.
  8. Adjustable Band Hangers (MSS Type 9): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8.
  9. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8.
  10. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 8.
  11. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 3.
  12. U-Bolts (MSS Type 24): For support of heavy pipes NPS 1/2 to NPS 30.
  13. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
  14. Pipe Saddle Supports (MSS Type 36): For support of pipes NPS 4 to NPS 36, with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate.
  15. Pipe Stanchion Saddles (MSS Type 37): For support of pipes NPS 4 to NPS 36, with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate, and with U-bolt to retain pipe.
  16. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes NPS 2-1/2 to NPS 36 if vertical adjustment is required, with steel-pipe base stanchion support and cast-iron floor flange.
  17. Single-Pipe Rolls (MSS Type 41): For suspension of pipes NPS 1 to NPS 30, from two rods if longitudinal movement caused by expansion and contraction might occur.
  18. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes NPS 2-1/2 to NPS 24, from single rod if horizontal movement caused by expansion and contraction might occur.
  19. Complete Pipe Rolls (MSS Type 44): For support of pipes NPS 2 to NPS 42 if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
  20. Pipe Roll and Plate Units (MSS Type 45): For support of pipes NPS 2 to NPS 24 if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
  21. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes NPS 2 to NPS 30 if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.
- K. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24.
  2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers NPS 3/4 to NPS 24 if longer ends are required for riser clamps.
- L. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.

2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.
  3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
  4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
  5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F piping installations.
- M. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
  2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joint construction, to attach to top flange of structural shape.
  3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
  4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
  5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
  6. C-Clamps (MSS Type 23): For structural shapes.
  7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
  8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
  9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
  10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
  11. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
  12. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
    - a. Light (MSS Type 31): 750 lb.
    - b. Medium (MSS Type 32): 1500 lb.
    - c. Heavy (MSS Type 33): 3000 lb.
  13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
  14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
  15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.
- N. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
  2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
  3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.
- O. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
  2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.

3. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41, roll hanger with springs.
  4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
  5. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.
  6. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.
  7. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.
  8. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
    - a. Horizontal (MSS Type 54): Mounted horizontally.
    - b. Vertical (MSS Type 55): Mounted vertically.
    - c. Trapeze (MSS Type 56): Two vertical-type supports and one trapeze member.
- P. Comply with MSS SP-69 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.
- Q. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.
- R. Use mechanical-expansion anchors instead of building attachments where required in concrete construction.

**END OF SECTION**

## SECTION 23 05 48 - VIBRATION CONTROLS FOR HVAC PIPING AND EQUIPMENT

### PART 1 - GENERAL

#### 1.1 SUMMARY

- A. This Section includes the following:
1. Isolation pads.
  2. Isolation mounts.
  3. Restrained elastomeric isolation mounts.
  4. Restrained spring isolators.
  5. Housed spring mounts.
  6. Elastomeric hangers.
  7. Spring hangers.
  8. Spring hangers with vertical-limit stops.
  9. Restrained vibration isolation roof-curb rails.
  10. Restraining braces and cables.
  11. Inertia, vibration isolation equipment bases.

#### 1.2 DEFINITIONS

- A. IBC: International Building Code.

#### 1.3 SUBMITTALS

- A. Product Data: For the following:
1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
    - a. Annotate to indicate application of each product submitted and compliance with requirements.
  2. Interlocking Snubbers: Include ratings for horizontal, vertical, and combined loads.
  3. Submit manufacturers recommendations for vibration isolation of their equipment.
- B. Field quality-control test reports.

#### 1.4 QUALITY ASSURANCE

- A. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Maintain ASHRAE criteria for average noise criteria curves for all equipment at full load condition.

### PART 2 - PRODUCTS

## 2.1 VIBRATION ISOLATORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Ace Mountings Co., Inc.
  2. Amber/Booth Company, Inc.
  3. Isolation Technology, Inc.
  4. Kinetics Noise Control.
  5. Mason Industries.
  6. Vibration Eliminator Co., Inc.
  7. Vibration Isolation.
  8. Vibration Mountings & Controls, Inc.
- B. Pads: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.
1. Resilient Material: Oil- and water-resistant neoprene.
- C. Mounts: Double-deflection type, with molded, oil-resistant rubber, hermetically sealed compressed fiberglass, or neoprene isolator elements with factory-drilled, encapsulated top plate for bolting to equipment and with baseplate for bolting to structure. Color-code or otherwise identify to indicate capacity range.
1. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.
  2. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.
- D. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with limit-stop restraint.
1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to 1/4-inch-thick, neoprene or rubber isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
  2. Restraint: Seismic or limit stop as required for equipment and authorities having jurisdiction.
  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.
- E. Housed Spring Mounts: Housed spring isolator with integral snubbers.
1. Housing: Ductile-iron or steel housing to provide all-directional seismic restraint.
  2. Base: Factory drilled for bolting to structure.
  3. Snubbers: Vertically adjustable to allow a maximum of 1/4-inch travel up or down before contacting a resilient collar.
- F. Elastomeric Hangers: Single or double-deflection type, fitted with molded, oil-resistant elastomeric isolator elements bonded to steel housings with threaded connections for hanger rods. Color-code or otherwise identify to indicate capacity range.

- G. Spring Hangers with Vertical-Limit Stop: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression and with a vertical-limit stop.
  - 1. 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.
  - 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. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
  - 7. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
  - 8. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.
- H. Pipe Riser Resilient Support: All-directional, acoustical pipe anchor consisting of 2 steel tubes separated by a minimum of 1/2-inch-thick neoprene. Include steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions. Design support for a maximum load on the isolation material of 500 psig and for equal resistance in all directions.
- I. Resilient Pipe Guides: Telescopic arrangement of 2 steel tubes or post and sleeve arrangement separated by a minimum of 1/2-inch-thick neoprene. Where clearances are not readily visible, a factory-set guide height with a shear pin to allow vertical motion due to pipe expansion and contraction shall be fitted. Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

## 2.2 RESTRAINED VIBRATION ISOLATION ROOF-CURB RAILS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
  - 1. Amber/Booth Company, Inc.
  - 2. Isolation Technology, Inc.
  - 3. Kinetics Noise Control.
  - 4. Mason Industries.
  - 5. Thybar Corporation.
  - 6. Vibration Eliminator Co., Inc.
  - 7. Vibration Isolation.
  - 8. Vibration Mountings & Controls, Inc.
- B. General Requirements for Restrained Vibration Isolation Roof-Curb Rails: Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment and to withstand wind forces.
- C. Lower Support Assembly: Formed sheet-metal section containing adjustable and removable steel springs that support upper frame. Upper frame shall provide continuous support for equipment and shall be captive to resiliently resist wind forces. 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.

- D. Spring Isolators: Adjustable, restrained spring isolators shall be mounted on 1/4-inch-thick, 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.
1. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with wind restraint.
    - a. Housing: Steel with resilient vertical-limit stops and adjustable equipment mounting and leveling bolt.
    - b. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
    - c. Minimum Additional Travel: 50 percent of the required deflection at rated load.
    - d. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
    - e. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
  2. Pads: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.
    - a. Resilient Material: Oil- and water-resistant standard neoprene.
- 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.

## 2.3 VIBRATION ISOLATION EQUIPMENT BASES

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. Amber/Booth Company, Inc.
  2. Isolation Technology, Inc.
  3. Kinetics Noise Control.
  4. Mason Industries.
  5. Vibration Eliminator Co., Inc.
  6. Vibration Isolation.
  7. Vibration Mountings & Controls, Inc.
- B. Steel Base: 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.
    - a. Include supports for suction and discharge elbows for pumps.
  2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. 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.
- C. Inertia Base: Factory-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.
  - a. Include supports for suction and discharge elbows for pumps.
2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. 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.

## 2.4 FACTORY FINISHES

- A. Finish: Manufacturer's standard primer-coat finish ready for field painting.
- B. Finish: Manufacturer's standard paint applied to factory-assembled and -tested equipment before shipping.
  1. Powder coating on springs and housings.
  2. All hardware shall be galvanized. Hot-dip galvanize metal components for exterior use.
  3. Baked enamel or powder coat for metal components on isolators for interior use.
  4. Color-code or otherwise mark vibration isolation and wind-control devices to indicate capacity range.

## PART 3 - EXECUTION

### 3.1 EXAMINATION

- A. Examine areas and equipment to receive vibration isolation and wind-control devices for compliance with requirements for installation tolerances and other conditions affecting performance.
- 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. 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.
- B. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static.

### 3.3 VIBRATION-CONTROL RESTRAINT DEVICE INSTALLATION

- A. Comply with requirements in Division 07 Section "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.

B. Equipment Restraints:

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 providing required submittals for component.

C. Piping Restraints:

1. Comply with requirements in MSS SP-127.
2. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c.
3. Brace a change of direction longer than 12 feet.

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

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

F. 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.

G. 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.

H. 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 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:

1. Measure isolator restraint clearance.
2. Measure isolator deflection.

3. Verify snubber minimum clearances.

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

### 3.5 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.

C. Adjust active height of spring isolators.

D. Adjust restraints to permit free movement of equipment within normal mode of operation.

**END OF SECTION**

## SECTION 23 05 53 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

### PART 1 - GENERAL

#### 1.1 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.

#### 1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Valve numbering scheme.

#### 1.3 COORDINATION

- 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.

### PART 2 - PRODUCTS

#### 2.1 EQUIPMENT LABELS

- A. Plastic Labels for Equipment:
  - 1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.
  - 2. Letter Color: White.
  - 3. Background Color: Black.
  - 4. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
  - 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: 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
  - 7. Fasteners: Stainless-steel screws.

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

- B. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified.
- C. 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), plus 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. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.
- B. Letter Color: Black.
- C. Background Color: Yellow.
- D. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
- E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
- F. Minimum Letter Size: 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-fourths the size of principal lettering.
- G. Fasteners: Stainless-steel screws.
- H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- I. Label Content: Include caution and warning information, plus emergency notification instructions.

## 2.3 PIPE LABELS

- A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.
- B. Pretensioned Pipe Labels: Pre-coiled, semirigid plastic formed to cover full circumference of pipe and to attach to pipe without fasteners or adhesive.
- C. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.
- D. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings, 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.
  - 2. Lettering Size: At least 1-1/2 inches high.

## 2.4 DUCT LABELS

- A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.
- B. Letter Color: White.
- C. Background Color: Black.
- D. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
- E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
- F. Minimum Letter Size: 3/4 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
- G. Fasteners: Stainless-steel screws.
- H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- I. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings, 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. Lettering Size: At least 1-1/2 inches high.

## 2.5 STENCILS

- A. Stencils: Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-1/4 inches for ducts; and minimum letter height of 3/4 inch for access panel and door labels, equipment labels, and similar operational instructions.
  - 1. Stencil Material: Fiberboard or metal.
  - 2. Stencil Paint: Exterior, gloss, acrylic enamel black unless otherwise indicated. Paint may be in pressurized spray-can form.
  - 3. Identification Paint: Exterior, acrylic enamel in colors according to ASME A13.1 unless otherwise indicated.

## 2.6 VALVE TAGS

- A. Valve Tags: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.
  - 1. Tag Material: Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.
  - 2. Fasteners: Brass wire-link or beaded chain; or S-hook.
- B. 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

- A. Warning Tags: Preprinted or partially preprinted, accident-prevention tags, of plasticized card stock with matte finish suitable for writing.
  1. Size: Approximately 4 by 7 inches.
  2. Fasteners: Brass grommet and wire.
  3. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."
  4. Color: Yellow background with black lettering.

## PART 3 - EXECUTION

### 3.1 PREPARATION

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

### 3.2 EQUIPMENT LABEL INSTALLATION

- A. Install or permanently fasten labels on each major item of mechanical equipment.
- B. Locate equipment labels where accessible and visible.

### 3.3 PIPE LABEL INSTALLATION

- A. Piping Color-Coding: Painting of piping is specified in Division 09 Section ".".
- 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, on each piping system.
  1. Identification Paint: Use for contrasting background.
  2. Stencil Paint: Use for pipe marking.
- C. 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 (less than 10 feet) for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
  3. Near penetrations 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 30 feet along each run. Reduce intervals to 15 feet in areas of congested piping and equipment.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

D. Pipe Label Color Schedule:

1. Chilled-Water Piping:
  - a. Background Color: White.
  - b. Letter Color: Blue.
2. Condenser-Water Piping:
  - a. Background Color: White.
  - b. Letter Color: Green
3. Heating Water Piping:
  - a. Background Color: White.
  - b. Letter Color: Red.
4. Refrigerant Piping:
  - a. Background Color: White.
  - b. Letter Color: Black.
5. Low-Pressure Steam Piping:
  - a. Background Color: White.
  - b. Letter Color: Black.
6. High-Pressure Steam Piping:
  - a. Background Color: White.
  - b. Letter Color: Black.
7. Steam Condensate Piping:
  - a. Background Color: White.
  - b. Letter Color: Red.

3.4 DUCT LABEL INSTALLATION

- A. Install self-adhesive duct labels with permanent adhesive on air ducts in the following color codes:
1. Blue: For cold-air supply ducts.
  2. Yellow: For hot-air supply ducts.
  3. Green: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
  4. ASME A13.1 Colors and Designs: For hazardous material exhaust.

- B. Stenciled Duct Label Option: Not acceptable
- C. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of 50 feet in each space where ducts are exposed or concealed by removable ceiling system.

### 3.5 VALVE-TAG INSTALLATION

- 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:
  - 1. Valve-Tag Size and Shape:
    - a. Chilled Water: 1-1/2 inches, round.
    - b. Condenser Water: 1-1/2 inches, round.
    - c. Refrigerant: 1-1/2 inches, round.
    - d. Hot Water: 1-1/2 inches, round.
    - e. Low-Pressure Steam: 1-1/2 inches, round.
    - f. High-Pressure Steam: 2", round.
    - g. Steam Condensate: 2" , round.
  - 2. Valve-Tag Color:
    - a. Chilled Water: Blue.
    - b. Condenser Water: Green.
    - c. Refrigerant: Black.
    - d. Hot Water: Green.
    - e. Low-Pressure Steam: Yellow.
    - f. High-Pressure Steam: Red.
    - g. Steam Condensate: Green.
  - 3. Letter Color:
    - a. Chilled Water: White.
    - b. Condenser Water: White.
    - c. Refrigerant: White.
    - d. Hot Water: White.
    - e. Gas: White.
    - f. Low-Pressure Steam: White.
    - g. High-Pressure Steam: White.
    - h. Steam Condensate: White.

### 3.6 WARNING-TAG INSTALLATION

- A. Write required message on, and attach warning tags to, equipment and other items where required.

**END OF SECTION**

## **SECTION 23 05 93 - TESTING, ADJUSTING, AND BALANCING FOR HVAC**

### **PART 1 - GENERAL**

#### 1.1 SUMMARY

- A. Section Includes:
  - 1. Balancing Air Systems:
    - a. Constant-volume air systems.
    - b. Variable-air-volume systems.
    - c. Return Air system
    - d. Exhaust systems.

#### 1.2 DEFINITIONS

- A. AABC: Associated Air Balance Council.
- B. NEBB: National Environmental Balancing Bureau.
- C. TAB: Testing, adjusting, and balancing.
- D. TABB: Testing, Adjusting, and Balancing Bureau.
- E. TAB Specialist: An entity engaged to perform TAB Work.

#### 1.3 SUBMITTALS

- A. Qualification Data: Within 30 days of Contractor's Notice to Proceed, submit documentation that the TAB contractor and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.
- B. Contract Documents Examination Report: Within 30 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 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.
- D. Certified TAB reports.
- E. Sample report forms.
- F. 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.

#### 1.4 QUALITY ASSURANCE

- A. TAB Contractor Qualifications: Engage a TAB entity certified by NEBB.
  - 1. TAB Field Supervisor: Employee of the TAB contractor and certified by NEBB.
  - 2. TAB Technician: Employee of the TAB contractor and who is certified by NEBB as a TAB technician.
- B. TAB Report Forms: Use standard TAB contractor's forms approved by Commissioning Authority or Mechanical Engineer.
- C. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE 111, Section 5, "Instrumentation."

#### 1.5 PROJECT CONDITIONS

- A. 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.

#### 1.6 COORDINATION

- A. Notice: Provide seven days' advance notice for each test. Include scheduled test dates and times.
- B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.
- C. The preparation for and corrections necessary for the testing, adjusting and balancing of these systems, as described herein, are the responsibility of this contractor.
- D. As part of this project Construction Contract, the contractor shall make any changes or replacement to the sheaves, belts, dampers, valves, etc. required for correct balance as advised by the TAB Firm, at no additional cost to the owner.
- E. Contractor shall provide and coordinate the services of qualified, responsible subcontractors, suppliers and personnel as required to correct, repair and/or replace any and all deficient items or conditions found during the course of this project, including during the testing and adjusting and balancing period.
- F. In order that system may be properly tested, adjusted, and balanced, the Contractor shall operate system at Contractor's expense for the length of time necessary to properly verify the systems' completion and readiness for TAB.
- G. Project Contract completion schedules shall allow for sufficient time to permit the completion of TAB services prior to Owner occupancy. Contractor shall allow adequate time for the testing and balancing activities during the construction period and prior to the Substantial Completion as defined in this Construction Documents.
- H. The drawings and specifications indicate valves, damper and miscellaneous adjustment devices for the purpose of adjustment to obtain optimum operating conditions. Contractor shall be responsible for installing these devices in a manner that will leave the devices accessible and readily able to be adjusted. Contractor shall immediately correct any malfunction encountered

and reported to the Contractor by TAB personnel so that the balancing work can proceed with minimum delay.

## **PART 2 - PRODUCTS (Not Applicable)**

## **PART 3 - EXECUTION**

### **3.1 TAB SPECIALISTS**

- A. Subject to compliance with requirements, Testing, Adjusting and Balancing (TAB) of the air conditioning systems and domestic water systems will be performed by an impartial technical TAB firm employed by the contractor, engage one of the following:
1. Engineering Air Balance, Inc.
  2. Technical Air Balance, Inc.
  3. Precision Air of Texas
  4. Page Commissioning and Air Balance
  5. Any TAB firm approved by the engineer providing equal or better quality of work as the firms above.

### **3.2 EXAMINATION**

- 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 systems for installed 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 accessible.
- C. Examine the approved submittals for HVAC systems and equipment.
- 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 meet the leakage class of connected ducts as specified in Division 23 Section "Metal Ducts" and 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 filters and verify that bearings are greased, belts are aligned and tight, 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 are replaced by permanent screens with indicated perforations.
- L. Examine three-way valves for proper installation for their intended function of 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 strategies and step-by-step procedures.
- B. Complete system-readiness checks and prepare reports. Verify the following:
  - 1. Permanent electrical-power wiring is complete.
  - 2. VFD's have been set up and operation checks by VFD manufacturer
  - 3. Automatic temperature-control systems are operational.
  - 4. Equipment and duct access doors are securely closed.
  - 5. Balance, smoke, and fire dampers are open.
  - 6. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
  - 7. Windows and doors can be closed so indicated conditions for system operations can be met.
  - 8. Blower door and duct blaster tests have been performed.

### 3.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

- A. Perform testing and balancing procedures on each system according to the procedures contained in NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" and in this Section.
  - 1. Comply with requirements in ASHRAE 62.1-2019, Section on "Air Balancing."

- B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.
  - 1. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Division 23 Section "HVAC 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) 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. Crosscheck 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 VFD's have been commissioned by manufacturer certified personnel.
- 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 Division 23 Section "Metal Ducts."
- M. Review duct leakage test report and that it meets seal classification as stated in drawings

### 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. Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.

2. Measure fan static pressures as follows to determine actual static pressure:
    - a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.
    - b. Measure static pressure directly at the fan outlet or through the flexible connection.
    - c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.
    - d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.
  3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.
    - a. Report the cleanliness status of filters and the time static pressures are measured.
  4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.
  5. 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.
  6. Obtain approval from Engineer or Owner for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in Division 23 Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
  7. 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 will occur. 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 within specified tolerances.
1. Measure airflow of submain and branch ducts.
    - a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.
  2. Measure static pressure at a point downstream from the balancing damper, and adjust volume dampers until the proper static pressure is achieved.
  3. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.
- C. Measure air outlets and inlets without making adjustments.
1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

- D. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using branch volume dampers rather than extractors and the dampers at air terminals.
  - 1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
  - 2. Adjust patterns of adjustable outlets for proper distribution without drafts.

### 3.7 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

- A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a minimum set-point airflow with the remainder at maximum-airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.
- B. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
  - 1. Set outdoor-air dampers at minimum, and set return- and exhaust-air dampers at a position that simulates full-cooling load.
  - 2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure 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.
  - 3. Measure total system airflow. Adjust to within indicated airflow.
  - 4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
  - 5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.
    - a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.
  - 6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.
    - a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.
  - 7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
  - 8. Record final fan-performance data.
- C. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance variable-air-volume systems the same as described for constant-volume air systems.
  2. Set terminal units and supply fan at full-airflow condition.
  3. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
  4. Readjust fan airflow for final maximum readings.
  5. Measure operating static pressure at the sensor that controls the supply fan if one is installed, and verify operation of the static-pressure controller.
  6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.
  7. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.
    - a. If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.
  8. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.
    - a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.
- D. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.
  2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.
  3. Set terminal units at full-airflow condition.
  4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
  5. Adjust terminal units for minimum airflow.
  6. Measure static pressure at the sensor.
  7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

### 3.8 PROCEDURES FOR 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. Efficiency rating.
  5. Nameplate and measured voltage, each phase.
  6. Nameplate and measured amperage, each phase.
  7. VFD Hertz to achieve design flow.

- B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass of the controller to prove proper operation. Record observations including name of controller manufacturer, model number, serial number, and nameplate data.

### 3.9 PROCEDURES FOR CONDENSING UNITS

- A. Verify proper rotation of fans.
- B. Measure entering- and leaving-air temperatures.
- C. Record compressor data.

### 3.10 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.
  - 4. Dry-bulb temperature of entering and leaving air.
  - 5. Wet-bulb temperature of entering and leaving air for cooling coils.
  - 6. Airflow.
  - 7. Air pressure drop.
- 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 and at each incremental stage.
  - 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. Air pressure drop.
  - 4. 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.
  - 4. Air pressure drop.
  - 5. Refrigerant suction pressure and temperature.

### 3.11 TOLERANCES

- A. Set HVAC system's air flow rates and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 10 percent.
2. Air Outlets and Inlets: Plus or minus 10 percent.
3. Heating-Water Flow Rate: Plus or minus 10 percent.
4. Cooling-Water Flow Rate: Plus or minus 10 percent.

### 3.12 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 biweekly 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.

### 3.13 FINAL REPORT

- 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.
- 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 contractor.
  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 air flow 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. Air flow 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. 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.
- H. 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 air flow rate in cfm.
    - h. Indicated velocity in fpm.
    - i. Actual air flow rate in cfm.
    - j. Actual average velocity in fpm.
    - k. Barometric pressure in psig.
- I. 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. Air flow rate in cfm.
  - b. Air velocity in fpm.
  - c. Preliminary air flow rate as needed in cfm.
  - d. Preliminary velocity as needed in fpm.
  - e. Final air flow rate in cfm.
  - f. Final velocity in fpm.
  - g. Space temperature in deg F.
- J. 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. Air flow 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.
- K. Instrument Calibration Reports:
1. Report Data:
    - a. Instrument type and make.
    - b. Serial number.
    - c. Application.
    - d. Dates of use.
    - e. Dates of calibration.

### 3.14 INSPECTIONS

- A. Initial Inspection:
1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.
  2. Check the following for each system:
    - a. Measure airflow of at least 10 percent of air outlets.
    - b. Measure water flow of at least 5 percent of terminals.
    - c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
    - d. Verify that balancing devices are marked with final balance position.
    - e. Note deviations from the Contract Documents in the final report.
- B. Final Inspection:

1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by Engineer.
  2. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of Construction Manager.
  3. Design Engineer 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.
  4. 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."
  5. 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.
- C. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:
1. 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 contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.
- D. Prepare test and inspection reports.

### 3.15 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**

## SECTION 23 07 13 - DUCT INSULATION

### PART 1 - GENERAL

#### 1.1 SUMMARY

- A. Perform all work required to provide and install ductwork insulation and jackets indicated by the contract documents with supplementary items necessary for proper installation.
- B. Section includes insulating the following duct services:
  - 1. Indoor, concealed and exposed supply and outdoor air.
  - 2. Indoor, concealed and exposed return located in unconditioned space.
  - 3. Indoor, concealed and exposed, Type I, commercial, kitchen hood exhaust.
  - 4. Indoor, concealed and exposed oven and ware-wash exhaust.
  - 5. Indoor, concealed and exposed exhaust between isolation damper and penetration of building exterior.
  - 6. Outdoor, concealed and exposed supply and return.

#### 1.2 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. Qualification Data: For qualified Installer.

#### 1.3 QUALITY ASSURANCE

- 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.
- B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, 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.

#### 1.4 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

## 1.5 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Division 23 Section "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.
- D. Coordinate rated architectural walls around grease ducting system.

## 1.6 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

- A. All material shall meet or exceed all applicable referenced standards, federal, state, and local requirements, and conform to codes and ordinances of authorities having jurisdiction.
- B. 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.
- C. Products shall not contain asbestos, lead, mercury, or mercury compounds.
- D. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
- E. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- F. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
- G. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, Type III with factory applied FSK jacket.
  - 1. Products: Subject to compliance with requirements, provide one of the following:
    - a. CertainTeed Corp.; SoftTouch Duct Wrap.
    - b. Johns Manville; Microlite.

- c. Knauf Insulation; Friendly Feel Duct Wrap.
  - d. Manson Insulation Inc.; Alley Wrap.
  - e. Owens Corning; SOFTR All-Service Duct Wrap.
- H. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation with factory applied FSK jacket.
- 1. Products: Subject to compliance with requirements, provide one of the following:
    - a. CertainTeed Corp.; Commercial Board.
    - b. Fibrex Insulations Inc.; FBX.
    - c. Johns Manville; 800 Series Spin-Glas.
    - d. Knauf Insulation; Insulation Board.
    - e. Manson Insulation Inc.; AK Board.
    - f. Owens Corning; Fiberglas 700 Series.

## 2.2 FIRE-RATED INSULATION SYSTEMS

- A. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with FSK jacket that is tested and certified to provide a 2-hour fire rating by an NRTL acceptable to authorities having jurisdiction.
- 1. Products: Subject to compliance with requirements, provide one of the following:
    - a. CertainTeed Corp.; FlameChek.
    - b. Johns Manville; Firetemp Wrap.
    - c. Nelson Fire Stop Products; Nelson FSB Flameshield Blanket.
    - d. Thermal Ceramics; FireMaster Duct Wrap.
    - e. 3M; Fire Barrier Wrap Products.
    - f. Unifrax Corporation; FyreWrap.

## 2.3 ADHESIVES

- 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. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
- 1. Products: Subject to compliance with requirements, provide one of the following:
    - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.
    - b. Eagle Bridges - Marathon Industries; 225.
    - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60/85-70.
    - d. Mon-Eco Industries, Inc.; 22-25.
  - 2. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

## 2.4 MASTICS

- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.
- For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below ambient services.
- Products: Subject to compliance with requirements, provide the following:
    - Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.
    - Vimasco Corporation; 749.
  - Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
  - Service Temperature Range: Minus 20 to plus 180 deg F.
  - Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
- C. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
- Products: Subject to compliance with requirements, provide one of the following:
    - Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.
    - Eagle Bridges - Marathon Industries; 550.
    - Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
    - Mon-Eco Industries, Inc.; 55-50.
    - Vimasco Corporation; WC-1/WC-5.
  - Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
  - Service Temperature Range: Minus 20 to plus 180 deg F.
  - Solids Content: 60 percent by volume and 66 percent by weight.

## 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.
- For indoor applications, use lagging adhesives that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
  - Products: Subject to compliance with requirements, provide one of the following:
    - Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-50 AHV2.
    - Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-36.
    - Vimasco Corporation; 713 and 714.

3. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over duct insulation.
4. Service Temperature Range: 0 to plus 180 deg F.
5. Color: White.

## 2.6 SEALANTS

### A. FSK and Metal Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, provide one of the following:
  - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
  - b. Eagle Bridges - Marathon Industries; 405.
  - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 95-44.
  - d. Mon-Eco Industries, Inc.; 44-05.
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. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

## 2.7 FACTORY-APPLIED JACKETS

### A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.

## 2.8 FIELD-APPLIED JACKETS

### A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

### B. Metal Jacket:

1. Products: Subject to compliance with requirements, provide one of the following:
  - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Metal Jacketing Systems.
  - b. ITW Insulation Systems; Aluminum and Stainless Steel Jacketing.
  - c. RPR Products, Inc.; Insul-Mate.
2. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.
  - a. Finish and thickness are indicated in field-applied jacket schedules.

- b. Moisture Barrier for Indoor Applications: 3-mil-thick, heat-bonded polyethylene and kraft paper.
  - c. Moisture Barrier for Outdoor Applications: 3-mil-thick, heat-bonded polyethylene and kraft paper.
- C. 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 aluminum-foil facing.
- 1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
    - a. Polyguard Products, Inc.; Alumaguard 60.

## 2.9 TAPES

- A. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.
- 1. Products: Subject to compliance with requirements, provide one of the following:
    - a. ABI, Ideal Tape Division; 491 AWF FSK.
    - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
    - c. Compac Corporation; 110 and 111.
    - d. Venture Tape; 1525 CW NT, 1528 CW, and 1528 CW/SQ.
  - 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.
- B. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.
- 1. Products: Subject to compliance with requirements, provide one of the following:
    - a. ABI, Ideal Tape Division; 488 AWF.
    - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
    - c. Compac Corporation; 120.
    - d. Venture Tape; 3520 CW.
  - 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.

## 2.10 SECUREMENTS

- A. Bands:

1. Products: Subject to compliance with requirements, provide one of the following:
    - a. ITW Insulation Systems; Gerrard Strapping and Seals.
    - b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs.
  2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304; 0.015 inch thick, 1/2 inch wide with wing seal or closed seal.
  3. Aluminum: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 1/2 inch wide with wing seal or closed seal.
  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, 0.135-inch-diameter shank, length to suit depth of insulation indicated.
    - a. Products: Subject to compliance with requirements, provide one of the following:
      - 1) AGM Industries, Inc.; CWP-1.
      - 2) GEMCO; CD.
      - 3) Midwest Fasteners, Inc.; CD.
      - 4) Nelson Stud Welding; TPA, TPC, and TPS.
  2. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch-diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.
    - a. Products: Subject to compliance with requirements, provide one of the following:
      - 1) AGM Industries, Inc.; CHP-1.
      - 2) GEMCO; Cupped Head Weld Pin.
      - 3) Midwest Fasteners, Inc.; Cupped Head.
      - 4) Nelson Stud Welding; CHP.
  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. Products: Subject to compliance with requirements, provide one of the following:
      - 1) AGM Industries, Inc.; Tactoo Perforated Base Insul-Hangers.
      - 2) GEMCO; Perforated Base.
      - 3) Midwest Fasteners, Inc.; Spindle.
    - b. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
    - c. Spindle: Copper- or zinc-coated, low-carbon 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. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick, galvanized-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. Products: Subject to compliance with requirements, provide one of the following:
    - 1) AGM Industries, Inc.; RC-150.
    - 2) GEMCO; R-150.
    - 3) Midwest Fasteners, Inc.; WA-150.
    - 4) Nelson Stud Welding; Speed Clips.
  - b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.
- C. Staples: Outward-clinching insulation staples, nominal 3/4-inch-wide, stainless steel or Monel.
- D. Wire: 0.062-inch soft-annealed, galvanized steel.
  1. 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:
    - a. C & F Wire.

### **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 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.

- O. Provide external insulation to all supply ceiling diffusers connectors and on top of diffusers.

### 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 Division 07 Section "Penetration Firestopping" firestopping and fire-resistant joint sealers.
- 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 Division 07 Section "Penetration Firestopping."

### 3.5 INSTALLATION OF MINERAL-FIBER INSULATION

- A. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.
  - 1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.

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.
1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.
  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 over compress 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.

### 3.6 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 Division 07 Section "Penetration Firestopping."

### 3.7 FINISHES

- A. Do not field paint aluminum or stainless-steel jackets.

### 3.8 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Tests and Inspections:
  - 1. Inspect ductwork, randomly selected by Architect and Engineers, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.
- C. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

### 3.9 DUCT INSULATION SCHEDULE, GENERAL

- A. Plenums and Ducts Requiring Insulation:
  - 1. Indoor, concealed and exposed supply and outdoor air.
  - 2. Return air duct located in unconditioned space.
  - 3. Indoor, concealed and exposed Type I, commercial, kitchen hood exhaust.
  - 4. Indoor, concealed and exposed oven and ware-wash exhaust.
  - 5. Indoor, concealed and exposed exhaust between isolation damper and penetration of building exterior.
  - 6. Outdoor, concealed and exposed supply and return.
- B. Items Not Insulated:
  - 1. Return-air duct in conditioned areas (plenums).
  - 2. Exhaust-air ductwork.
  - 3. Fume hood exhaust ductwork.
  - 4. Fibrous-glass ducts.
  - 5. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
  - 6. Factory-insulated flexible ducts.
  - 7. Factory-insulated plenums and casings.
  - 8. Flexible connectors.
  - 9. Vibration-control devices.
  - 10. Factory-insulated access panels and doors.

### 3.10 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

- A. Concealed or exposed, rectangular, round and flat-oval, supply-air, and outside-air duct outside mechanical rooms insulation shall be the following:
  - 1. Mineral-Fiber Blanket: 2 inches thick and 1.5-lb/cu. ft. nominal density.
- B. Concealed or exposed, rectangular, round and flat-oval, supply-air, and outside-air duct inside mechanical rooms insulation shall be the following:
  - 1. Mineral-Fiber Board: 2" inches thick and 3.0-lb/cu. ft. nominal density.
- C. Concealed or exposed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated blanket; thickness as required to achieve 2-hour fire rating.

3.11 OUTDOOR DUCT AND PLENUM INSULATION SCHEDULE

- A. Concealed or exposed, rectangular, round and flat-oval, supply-air, return-air and outside-air duct insulation shall be the following:
  - 1. Outdoor Mineral-Fiber Board: 2" inches thick and 3.0-lb/cu. ft. nominal density.
- B. Concealed or exposed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated blanket; thickness as required to achieve 2-hour fire rating.

3.12 INDOOR, FIELD-APPLIED JACKET SCHEDULE

- A. Not required.

3.13 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

- A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
- B. Ducts and Plenums, Concealed/exposed:
  - 1. Aluminum Corrugated: 0.020 inch thick
  - 2. Must be pitched to shed water. .

**END OF SECTION**

## SECTION 23 07 19 - HVAC PIPING INSULATION

### PART 1 - GENERAL

#### 1.1 SUMMARY

- A. Section includes insulating the following HVAC piping systems:
  - 1. Condensate drain piping, indoors and outdoors.
  - 2. Refrigerant suction and hot-gas piping, indoors and outdoors.
- B. All insulation values must comply with the applicable Energy Code as stated on the drawings and the application for which it is being used.
- C. Related Sections:
  - 1. Division 23 Section "HVAC Equipment Insulation."
  - 2. Division 23 Section "Duct Insulation."
  - 3. Division 23 Section "Underground Hydronic Piping" for loose-fill pipe insulation in underground piping outside the building.
  - 4. Division 33 Section "Underground Steam and Condensate Distribution Piping" for loose-fill pipe insulation in underground piping outside the building.

#### 1.2 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. 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.
- C. 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.
- D. Qualification Data: For qualified Installer.

- E. 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.
- F. Field quality-control reports.

### 1.3 QUALITY ASSURANCE

- 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.
- B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing and inspecting 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.

### 1.4 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

### 1.5 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Division 23 Section "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.
- C. Coordinate installation and testing of heat tracing.

### 1.6 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

- 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.
- 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 C 871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- E. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials.
  - 1. Products: Subject to compliance with requirements, provide one of the following:
    - a. Aeroflex USA, Inc.; Aerocel.
    - b. Armacell LLC; AP Armaflex.

## 2.2 INSULATING CEMENTS

- A. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449.
  - 1. Products: Subject to compliance with requirements, provide the following:
    - a. Ramco Insulation, Inc.; Ramcote 1200 and Quik-Cote.

## 2.3 ADHESIVES

- 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. Flexible Elastomeric Adhesive: Comply with MIL-A-24179A, Type II, Class I.
  - 1. Products: Subject to compliance with requirements, provide one of the following:
    - a. Aeroflex USA, Inc.; Aero seal.
    - b. Armacell LLC; Armaflex 520 Adhesive.
    - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-75.
    - d. K-Flex USA; R-373 Contact Adhesive.
  - 2. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

## 2.4 MASTICS

- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.

1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below-ambient services.

1. Products: Subject to compliance with requirements, provide the following:
  - a. Pittsote 404 Coating, Pittsburgh Corning.
  - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.
2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
5. Color: White.

## 2.5 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass, Phenolic, and Polyisocyanurate Products: Subject to compliance with requirements, provide one of the following:
  - a. Pittsburgh Corning Corporation: Pittseal CW sealant.
  - b. Pittsburgh Corning Corporation; Pittseal 444N
  - c. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
  - d. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-45.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Permanently flexible, elastomeric sealant.
4. Service Temperature Range: Minus 100 to plus 300 deg F.
5. Color: White or gray.
6. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. 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/Rose colored aluminum-foil facing.

1. Products: Subject to compliance with requirements, provide the following:
  - a. Pittsburgh Corning Corporation; Pittwrap SS Jacketing
  - b. Polyguard Products, Inc.; Alumaguard 60.

## 2.6 SECUREMENTS

A. Bands:

1. Products: Subject to compliance with requirements, provide one of the following:

- a. ITW Insulation Systems; Gerrard Strapping and Seals.
  - b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs.
2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304 or Type 316; 0.015 inch thick, 3/4 inch wide with wing seal or closed seal.
  3. Aluminum: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 3/4 inch wide with wing seal or closed seal.
  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. Staples: Outward-clinching insulation staples, nominal 3/4-inch-wide, stainless steel or Monel.

### **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.
  3. 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.
- B. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
- C. 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 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 application and finishing.
- 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 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.
  - 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 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 pipe flanges and fittings.
- M. Cut insulation in a manner to avoid compressing insulation more than 75 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 similar 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.
4. Manholes.
5. Handholes.
6. Cleanouts.

### 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.

### 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.
- B. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:
1. Install insulation over fittings, valves, strainers, flanges, 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 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 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 used for adjacent pipe. Overlap adjoining pipe insulation by not less than two 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 used for adjacent pipe. Overlap adjoining pipe insulation by not less than two 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 and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
  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.
  9. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.
- 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.
- 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 adjoining pipe insulation.
  2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two 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 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 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 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.

3.7 FIELD-APPLIED JACKET INSTALLATION

3.8 FINISHES

- A. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.
- B. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.
- C. Do not field paint aluminum or stainless-steel jackets.

3.9 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Tests and Inspections:
  1. 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. Locations of straight pipe, three locations of threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of

threaded valves, and three locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General" Article.

- C. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

### 3.10 PIPING INSULATION SCHEDULE, GENERAL

- A. 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.

### 3.11 INDOOR PIPING INSULATION SCHEDULE

- A. Condensate and Equipment Drain Water below 60 Deg F:
  - 1. All Pipe Sizes: Insulation shall be one of the following:
    - a. Cellular Glass: 1-1/2 inches thick.
    - b. Flexible Elastomeric: 3/4 inch thick.
    - c. Phenolic: 1 inch thick.
- B. Refrigerant Suction and Hot-Gas Flexible Tubing:
  - 1. All Pipe Sizes: Insulation shall be the following:
    - a. Flexible Elastomeric: 1 inch thick.

### 3.12 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

- A. Refrigerant Suction and Hot-Gas Piping:
  - 1. All Pipe Sizes: Insulation shall be one of the following:
    - a. Flexible Elastomeric: 2 inches thick.
- B. Refrigerant Suction and Hot-Gas Flexible Tubing:
  - 1. All Pipe Sizes: Insulation shall be one of the following:
    - a. Flexible Elastomeric: 2 inches thick.

### 3.13 INDOOR, FIELD-APPLIED JACKET SCHEDULE

- 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:

1. None.

D. Piping, Exposed:

1. None.

3.14 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

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:

1. None.

D. Piping, Exposed:

1. Aluminum, Smooth with Z-Shaped Locking Seam: 0.020 inch thick.

2. Stainless Steel, Type 304, Smooth 2B Finish with Z-Shaped Locking Seam: 0.010 inch thick.

**END OF SECTION**

## SECTION 23 08 00 – PRE-COMMISSIONING OF HVAC

### PART 1 - GENERAL

#### 1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section. This section relates to the person verifying work prior to the Commissioning agent for the project as defined in Section 019113.

#### 1.2 SUMMARY

- A. Section includes commissioning process requirements for the following HVAC&R systems, assemblies, and equipment:
  - 1. Cooling generation systems, including **direct-expansion systems**.
  - 2. Distribution systems, including **air distribution (heating and cooling) systems, exhaust systems, air-handling equipment**.
  - 3. Terminal units, including **fan-coil units, electric heating**.
  - 4. Vibration and sound systems, including **vibration isolation devices, seismic restraints**.
  - 5. Controls and instrumentation, including **BAS, energy monitoring and control system, space thermostats/sensors**
  - 6. Systems testing and balancing verification, including all of the above system and equipment types
- B. Related Requirements:
  - 1. Section 019113 "General Commissioning Requirements" for general commissioning process requirements and Commissioning Coordinator responsibilities.

#### 1.3 DEFINITIONS

- A. BAS: Building automation system.
- B. DDC: Direct digital controls.
- C. HVAC&R: Heating, Ventilating, Air Conditioning, and Refrigeration.
- D. "Systems," "Subsystems," "Equipment," and "Components": Where these terms are used together or separately, they shall mean "as-built" systems, subsystems, equipment, and components.
- E. TAB: Testing, adjusting, and balancing.
- F. Commissioning in this section refers to the Pre-Commissioning of the systems and can be done by the contractors qualified personnel prior to the Commissioning agent.

#### 1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For **BAS and HVAC&R** Testing Technician.
- B. Construction Checklists: See related Sections for technical requirements for the following construction checklists:
  - 1. Vibration and seismic controls for HVAC&R piping and equipment.
  - 2. Instrumentation and controls for HVAC&R.
  - 3. Refrigerant piping.
  - 4. Metal ducts and accessories.
  - 5. Fans. Including exhaust fans for all air flows
  - 6. Particulate air filtration.
  - 7. Air-handling units.

#### 1.5 QUALITY ASSURANCE

- A. BAS Testing Technician Qualifications: Technicians to perform BAS construction checklist verification tests, construction checklist verification test demonstrations, commissioning tests, and commissioning test demonstrations shall have the following minimum qualifications:
  - 1. Journey-level or equivalent skill level with knowledge of BAS, HVAC&R, electrical concepts, and building operations.
  - 2. Minimum **three years'** experience installing, servicing, and operating systems manufactured by approved manufacturer.
  - 3. International Society of Automation (ISA) Certified Control Systems Technician (CCST) Level I or higher.
- B. HVAC&R Testing Technician Qualifications: Technicians to perform HVAC&R construction checklist verification tests, construction checklist verification test demonstrations, commissioning tests, and commissioning test demonstrations shall have the following minimum qualifications:
  - 1. Journeyman-level or equivalent skill level. Vocational School four-year program graduate or an Associates degree in mechanical systems, air conditioning, or similar field. Degree may be offset by three years' experience in servicing mechanical systems in the HVAC industry. Generally, required knowledge includes HVAC&R systems, electrical concepts, building operations, and application and use of tools and instrumentation to measure performance of HVAC&R equipment, assemblies, and systems.
  - 2. Minimum **three years'** experience installing, servicing, and operating systems manufactured by approved manufacturer.
  - 3. One of the following:
    - a. National Environmental Balancing Bureau (NEBB) Certified Testing, Adjusting, and Balancing Technician.
    - b. Associated Air Balance Council (AABC) Certified Test and Balance Technician.
    - c. Owner retains the right to waive NEBB or AABC Certification.
- C. Testing Equipment and Instrumentation Quality and Calibration: For test equipment and instrumentation required to perform HVAC&R commissioning work, perform the following:
  - 1. Submit test equipment and instrumentation list. For each equipment or instrument, identify the following:

- a. Equipment/instrument identification number.
  - b. Planned commissioning application or use.
  - c. Manufacturer, make, model, and serial number.
  - d. Calibration history, including certificates from agencies that calibrate the equipment and instrumentation.
2. Test equipment and instrumentation shall meet the following criteria:
- a. Capable of testing and measuring performance within the specified acceptance criteria.
  - b. Be calibrated at the manufacturer's recommended intervals with current calibration tags permanently affixed to the instrument being used.
  - c. Be maintained in good repair and operating condition throughout the duration of use on this Project.
  - d. Be recalibrated/repared if dropped or damaged in any way since last calibrated.
- D. Proprietary Test Instrumentation and Tools:
1. Equipment Manufacturer's Proprietary Instrumentation and Tools: For installed equipment included in the commissioning process, test instrumentation and tools manufactured or prescribed by equipment manufacturer to service, calibrate, adjust, repair, or otherwise work on its equipment or required as a condition of equipment warranty, perform the following:
    - a. Submit proprietary instrumentation and tools list. For each instrument or tool, identify the following:
      - 1) Instrument or tool identification number.
      - 2) Equipment schedule designation of equipment for which the instrument or tool is required.
      - 3) Manufacturer, make, model, and serial number.
      - 4) Calibration history, including certificates from agencies that calibrate the instrument or tool, where appropriate.
    - b. Include a separate list of proprietary test instrumentation and tools in the operation and maintenance manuals.
    - c. HVAC&R proprietary test instrumentation and tools become the property of Owner at the time of Substantial Completion.

## **PART 2 - PRODUCTS (Not Used)**

## **PART 3 - EXECUTION**

### **3.1 GENERAL TESTING REQUIREMENTS**

- A. Certify that HVAC&R systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents and approved Shop Drawings and submittals.
- B. Certify that HVAC&R instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents and approved Shop Drawings and submittals, and that pretest set points have been recorded.

- C. Certify that TAB procedures have been completed and that TAB reports have been submitted, discrepancies corrected, and corrective work approved.
- D. Set systems, subsystems, and equipment into operating mode to be tested according to approved test procedures (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).
- E. Measure capacities and effectiveness of systems, assemblies, subsystems, equipment, and components, including operational and control functions to verify compliance with acceptance criteria.
- F. Test systems, assemblies, subsystems, equipment, and components operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and response according to acceptance criteria.
- G. Construction Checklists: Prepare and submit detailed construction checklists for HVAC&R systems, subsystems, equipment, and components.
  - 1. Contributors to the development of construction checklists shall include, but are not limited to, the following:
    - a. HVAC&R systems and equipment installers.
    - b. TAB technicians.
    - c. HVAC&R instrumentation and controls installers.
- H. Perform tests using design conditions, whenever possible.
  - 1. Simulated conditions may, with approval of Architect, be imposed using an artificial load when it is impractical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by Commissioning Coordinator and document simulated conditions and methods of simulation. After tests, return configurations and settings to normal operating conditions.
  - 2. Commissioning test procedures may direct that set points be altered when simulating conditions is impractical.
  - 3. Commissioning test procedures may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are impractical.
- I. If tests cannot be completed because of a deficiency outside the scope of the HVAC&R system, document the deficiency and report it to Owner. After deficiencies are resolved, reschedule tests.
- J. Coordinate schedule with, and perform the following activities at the direction of, Commissioning Coordinator.
- K. Comply with construction checklist requirements, including material verification, installation checks, start-up, and performance tests requirements specified in Sections specifying HVAC systems and equipment.
- L. Provide technicians, instrumentation, tools, and equipment to complete and document the following:
  - 1. Performance tests.
  - 2. Demonstration of a sample of performance tests.
  - 3. Commissioning tests.

4. Commissioning test demonstrations.

### 3.2 TAB COMMISSIONING TESTS

#### A. TAB Verification:

1. Prerequisites: Completion of "Examination" Article requirements and correction of deficiencies, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
2. Completion of "Preparation" Article requirements for preparation of a TAB plan that includes strategies and step-by-step procedures, and system-readiness checks and reports, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
3. Scope: HVAC&R air systems and hydronic piping systems.
4. Purpose: Differential flow relationships intended to maintain air pressurization differentials between the various areas of Project.
5. Conditions of the Test:
  - a. Commissioning Test Demonstration Sampling Rate: As specified in "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
  - b. Systems operating in full cooling and heating mode **with minimum outside-air volume**.
  - c. Systems operating in full cooling or heating mode **with maximum outside-air volume**.
  - d. For measurements at air-handling units with economizer controls; systems operating in economizer mode with 100 percent outside air.
6. Acceptance Criteria:
  - a. Under all conditions, rechecked measurements comply with "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
  - b. Additionally, no rechecked measurement shall differ from measurements documented in the final report by more than two times the tolerances allowed.
  - c. Under all conditions, where the Contract Documents indicate a differential in airflow between supply and exhaust and/or return in a space, the differential relationship shall be maintained.

### 3.3 HEATING CONTROL SYSTEM COMMISSIONING TESTS

### 3.4 CENTRAL REFRIGERATION SYSTEM COMMISSIONING TESTS

#### A. Start and Stop Condensers:

1. Prerequisites: Installation verification of the following:
  - a. Input Device: See MI sheets.
  - b. Output Device: See MI sheets
  - c. Alarms: See MI sheets
  - d. Display the following at the operator's workstation:
    - 1) See MI sheets
2. Conditions of the Test:

- a. Verify Lockout: Start with condenser enable-input devices in the "disable" state to prevent start. One-by-one place the enable-input devices in the "enable" state, and then return each to the "disable" state before placing the next enable-input device to the "enable" state.
- b. Verify Start: Start with enable-input devices in the "disable" state to prevent start. One-by-one place the enable-input devices in the "enable" state.
- c. Verify Shutdown: Place all enable-input devices in the "enable" state to allow the pump(s) to start. One-by-one place the enable-input devices to their "disable" state, and then return each to the "enable" state before placing the next enable-input device to the "disable" state.
- d. Verify Schedule: Compare condenser start and stop schedule times with Owner-approved time-of-day schedule.
- e. Verify Alarms

### 3.5 AIR-HANDLING SYSTEM (Rooftop, Wall hung and Indoor AHU's) COMMISSIONING TESTS

#### A. Supply Fan(s) Variable-Volume Control:

1. Prerequisites: Installation verification of the following:
  - a. Volume Control Input Device: See MI sheets
  - b. Volume Control Output Device: see MI sheets
  - c. High-Pressure Input Device: see MI sheets
  - d. High-Pressure Output Device: see MI sheets
  - e. Display the following at the operator's workstation:
    - 1) See MI sheets
2. Scope: Variable-air-volume supply fan units and associated controls.
3. Purpose:
  - a. Supply-air discharge static pressure control.
  - b. Response to excess supply-air discharge static pressure condition.
4. Conditions of the Test:
  - a. Minimum supply-air flow.
  - b. Midrange Supply-Air Flow: **50 to 60** percent of maximum.
  - c. Maximum supply-air flow.
  - d. Excess supply-air discharge static pressure.
5. Acceptance Criteria:
  - a. At all supply-air flow rates, and during changes in supply-air flow, discharge air static pressure is at set point plus or minus 5 percent.
  - b. Fan stops and an alarm is initiated at the operator's workstation when supply-air discharge static pressure is at the excess static pressure plus or minus **10** percent.

#### B. Air-Handler Mixed-Air Control:

1. Prerequisites: Installation verification of the following:
  - a. Minimum Position Input Device: See MI sheets
  - b. Output Device: See MI sheets

- c. Heating Reset Input Device: see MI sheets
  - d. Cooling Reset Input Device: see MI sheets
  - e. Display the following at the operator's workstation:
    - 1) See MI sheets
2. Scope: Air handler with mixed-air control and associated controls.
3. Purpose:
- a. Occupied time control.
  - b. Minimum damper position control.
  - c. Heating reset control.
  - d. **Supply**-air temperature control.
  - e. Cooling reset control.
  - f. Unoccupied time control.
4. Conditions of the Test:
- a. Occupied Time Control: Start in unoccupied schedule. Advance to occupied schedule time.
  - b. Minimum Damper Position Control: Command system to mode in which minimum damper position is required.
  - c. Heating Reset Control: Create a call for heating.
  - d. **Supply**-Air Temperature Control: Override **supply**-air temperature set point to a value **2.0 deg F** above current **supply**-air temperature.
  - e. Cooling Reset Control: Override outdoor-air **temperature to a value that exceeds return-air temperature**.
  - f. Unoccupied Time Control: Advance to unoccupied schedule time.
  - g. Control Data Trend Log: Set up a data trend log of the following input device values and output device commands. Record data at **hourly recording frequency** intervals. Submit trend data for **24-hour** periods in which natural conditions require heating reset control, **supply**-air temperature control, and cooling reset control.
    - 1) Minimum position input device.
    - 2) Heating reset input device.
    - 3) **Supply**-air temperature input device.
    - 4) Cooling reset input device.
5. Acceptance Criteria:
- a. Occupied Time Control: Mixed-air control is active in occupied mode.
  - b. Minimum Damper Position Control: Controller **positions outdoor-air dampers to minimum position**.
  - c. Heating Reset Control: Controller **sets outdoor-air dampers to minimum position**.
  - d. **Supply**-Air Temperature Control: Controller modulates outdoor-, return-, and relief-air dampers to maintain temporary **supply**-air temperature set point plus or minus **2.0 deg F**.
  - e. Cooling Reset Control: Controller sets outdoor-air dampers to minimum position when outdoor-air **temperature exceeds return-air temperature**.
  - f. Unoccupied Time Control: Controller positions outdoor- and relief-air dampers closed and return-air dampers open.
  - g. Control Data Trend Log: Data verifies control according to sequence of control.

**END OF SECTION 23 08 00**

## SECTION 23 09 00 – HVAC AUTOMATION AND CONTROL

### 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 GENERAL REQUIREMENTS

- A. Conform to all, "Mechanical General Provisions".
- B. New BAS shall be a Carrier I-vue new from scratch with new server by others
- C. System shall be complete and fully functional using all Mechanical equipment in the building including stage system (installed as Phase 1) and exhaust fans.
- D. The "provide" in this Division shall be interpreted as "supply and install".
- E. Provide all required adapters between metric and imperial components.
- F. All equipment and materials be new, UL listed and BacNet certified, manufactured to minimum standard quoted including additional specified requirements.
- G. Where there is no alternative to supply equipment that is not listed, submit such equipment to Engineer for special inspection and obtain approval before delivery of equipment to site.
- H. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by the owner. Spare parts shall be available for at least ten years after completion of this contract.
- I. Use material and equipment available from regular production by manufacturer concerned.

#### 1.3 WORK INCLUDED

- A. Owner specifically wants standardized Building Automation Systems utilizing native BACnet, system and application controllers by Carrier I-vue.
- B. The system shall support standard Web browser access via the Owner's Intranet/Internet. It shall support a minimum of 100 simultaneous users with the ability to access graphical data and real time values simultaneously. (Refer to Section 7.16)
- C. Provide an open protocol Building Automation System (BAS) incorporating Direct Digital Control (DDC), equipment monitoring, and control consisting of: A PC based Operator Work Station (OWS) with color graphic data displays; Microcomputer based Building Controllers (BCs) and Microcomputer based Advanced Application Controllers (AACs) and Application Specific Controllers (ASCs) interfacing directly with sensors, actuators and environmental delivery systems (i.e., HVAC units, exhaust fans, lighting systems, etc.); electric controls and mechanical devices for all items indicated on drawings described herein including dampers, valves, panels and under stage pressurizing damper as well as stage to overhead bypass damper in duct.

- D. Owner has standardized the use of Direct Digital Controllers (DDC) and End Devices. No NEW pneumatic control devices shall be connected or incorporated into the BAS network. It applies to new installations as well as retrofit applications.
- E. Open Protocols by definition are to be BACnet (ASHRAE Standard 135 – Annex J) only.
- F. Provide BAS controllers (BCs, AACs and ASCs) based on native BACnet (ASHRAE Standard 135 – Annex J) protocols.
- G. Provide submittals, data entry, electrical installation, programming, startup, test and validation acceptance documentation, and system warranty.

#### 1.4 WORK BY OTHERS

- A. Access doors and setting in place of valves, flow meters, air pressure and differential taps, flow switches, dampers, air flow stations, and current transformers shall be by others.

#### 1.5 QUALITY ASSURANCE

- A. Codes and Approvals:
  - 1. Work, materials, and equipment shall comply with the National Electrical Code, ANSI/ASHRAE 135-2004: Data Communication Protocol for Building Automation and Control Systems (BACnet) and Authorities having jurisdiction over this work. All devices shall be UL or FM listed and labeled for the specific use, application and environment to which they are applied.
  - 2. The BAS shall comply with NFPA 90A Air Conditioning and 90B Warm Air Heating, Air Conditioning.
  - 3. All electronic equipment shall conform to the requirements of UL for electromagnetic emissions standards and placed in approved locations such that it does not interfere with building equipment or computers.
- B. Provide satisfactory operation without damage at 110% above and 85% below rated voltage and at 3 hertz variation in line frequency. Provide static, transient, and short circuit protection on all inputs and outputs. Communication lines shall be protected against incorrect wiring, static transients and induced magnetic interference. Bus connected devices shall be AC coupled, or equivalent so that any single device failure will not disrupt or halt bus communication.

#### 1.6 ABBREVIATIONS AND SYMBOLS

- A. All letter symbols and engineering unit abbreviations utilized in information displays ANSI/ISA S5.5 and printouts shall conform to ANSI 710.19/IEEE 260-letter symbols for SI and certain other units of measurement.
- B. Specification Nomenclature - Acronyms used in this specification are as follows:
  - AAC Advanced Application Controller
  - ASC Application Specific Controller
  - BAS Building Automation System
  - BC Building Controller
  - BIBB BACnet Interoperability Building Blocks
  - DDC Direct Digital Controls
  - GUI Graphical User Interface
  - HTTP Hyper Text Transfer Protocol
  - LAN Local Area Network
  - ODBC Open Database Connectivity protocol

OOT Object Oriented Technology  
OPC Object linking and embedding for Process Control  
OWS Operator Workstation  
PDA Personnel Data Assistant device  
PICS Protocol Implementation Conformance Statement  
PWS Portable Workstation  
SNVTS Standard Network Variables Types  
SQL Standard Query Language  
TCP/IP Transmission Control Protocol / Internet Protocol  
TCU Terminal Control Unit  
WAN Wide Area Network  
WAP Wireless Application Protocol device  
WBI Web Browser Interface  
XML Extensible Markup Language  
XIF External Interface Files

### 1.7 APPROVED CONTROL SYSTEMS

- A. Any vendors that are authorized dealers or distributors of the following control systems are acceptable:

Carrier - I-VUE

- B. BAS Systems Integration:

1. System must be open protocol and integrated with all existing and the possibility of future integration by any BacNet compliant device as stated above.

- C. Installer and Manufacturer Qualifications

1. Installer shall have an established working relationship with Control System Manufacturer
2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.
3. It is the intent of this specification to define an open protocol state-of-the-art distributed computerized Building Management and Control System which is user friendly, has known reliability, is extremely responsive, and which is to be designed, installed, implemented, and supported by a local office of approved bidders.
4. BAS contractor shall provide three locations of successful installations of similar open protocol computer-based systems. Sites provided must consist of more than 150 hardware inputs/outputs. Project sites must be local to the location of this project.

### 1.8 SYSTEM DESIGN

- A. The system shall consist of a network of Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), and Smart Actuators (SA). Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors.

- B. Systems utilizing gateways will not be considered. A gateway device is considered to be a device where only mapping of system points from one protocol to another occurs. A gateway device cannot perform higher-level energy management functions such as Outdoor Air Optimization, Electrical Demand Limiting and the like.

- C. The Building Automation System software shall employ object-oriented technology (OOT) for representation of all data and control devices within the system. The supplied system must incorporate the ability to access all data using standard Web browsers without requiring proprietary operator interface and configuration programs. An Open Database Connectivity (ODBC) or Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on a BAS server for all database access. Systems requiring proprietary database and user interface programs shall not be acceptable.
- D. A hierarchical topology is required to assure reasonable system response times and to manage the flow and sharing of data without unduly burdening the customer's internal Intranet network. Systems employing a flat single tiered architecture shall not be acceptable. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 5 seconds for network connected user interfaces. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 60 seconds for remote or dial-up connected user interfaces.

#### 1.9 BACnet

- A. Building Controllers (BCs). Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.
- B. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
- C. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.
- D. Smart Actuators (SAs). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.
- E. Smart Sensors (SSs). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135-2004, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.
- F. BACnet Communication.
  - 1. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.
  - 2. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
  - 3. Each AAC shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.
  - 4. Each ASC shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.
  - 5. Each SA shall reside on a BACnet network using the MS/TP Data Link/Physical layer protocol.
  - 6. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using MS/TP Data Link/Physical layer protocol.

#### 1.10 COMMUNICATION

- A. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.
- B. Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
- C. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
- D. Stand-Alone Operation. Each piece of equipment specified in the sequence of operation shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network.

#### 1.11 ENVIRONMENT

Controller hardware shall be suitable for anticipated ambient conditions.

- A. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -20°F to 140°F.
- B. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 32°F to 120°F.

#### 1.12 REAL-TIME CLOCK

- A. Controllers that perform scheduling shall have a real-time clock.

#### 1.13 SERVICEABILITY

- A. Controllers shall have diagnostic LEDs for power, communication, and processor.
- B. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
- C. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

#### 1.14 MEMORY

- A. Controller memory shall support operating system, database, and programming requirements.
- B. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
- C. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

1.15 IMMUNITY TO POWER AND NOISE

- A. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 3 ft.

1.16 POWERFAIL RESTART

- A. In the event of the loss of normal power, there shall be an orderly shutdown of all controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all controller configuration data, and battery back-up shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
- B. Upon restoration of normal power, the controller shall automatically resume full operation without manual intervention. The controllers shall incorporate random start sequences to ensure a power spike does not result.
- C. Controller memory shall not be lost during a power failure.
- D. The user shall have the capability of loading or re-loading all software via the OWS or the local terminal port.

1.17 DYNAMIC DATA ACCESS

- A. All operator devices, either network resident or connected via dial-up modems, shall have the ability to access all point status and application report data, or execute control functions for any and all other devices via the local area network. Access to data shall be based upon logical identification of building equipment.

1.18 INPUT AND OUTPUT INTERFACE

- A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.
- B. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.
- C. Binary Inputs. Binary inputs shall monitor the on and off signal from a remote device. Binary inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.
- D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.
- E. Analog Inputs. Analog inputs shall monitor low-voltage (0-10 Vdc), current (4-20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.
- F. Binary Outputs. Binary outputs shall send an on-or-off signal for on and off control. Building Controller binary outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

- G. Analog Outputs. Analog outputs shall send a modulating 0-10 Vdc or 4-20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.
- H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.
- I. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

#### 1.19 POWER SUPPLIES AND LINE FILTERING

- A. Power Supplies: Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with CEC requirements. Limit connected loads to 80% of rated capacity.
  - 1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes.
  - 2. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.
  - 3. Unit shall operate between 32°F and 120°F. EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
  - 4. Line voltage units shall be UL recognized and listed.
- B. Power Line Filtering
  - 1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:
    - a. Dielectric strength of 1000 V minimum
    - b. Response time of 10 nanoseconds or less
    - c. Transverse mode noise attenuation of 65 dB or greater
    - d. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

#### 1.20 AUXILIARY CONTROL DEVICES

- A. Electric Damper and Valve Actuators.
  - 1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.
  - 2. Spring-return Mechanism. Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
  - 3. Signal and Range. Proportional actuators shall accept a 0-10 Vdc or a 0-20 mA control signal and shall have a 2-10 Vdc or 4-20 mA operating range. (Floating motor actuators may be substituted for proportional actuators in terminal unit applications as described in paragraph 16.8)
  - 4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
  - 5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 60 in.-lb torque capacity shall have a manual crank.

- B. Binary Temperature Devices
  - 1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 55°F-85°F setpoint range, 2°F maximum differential, and vented ABS plastic cover.
  - 2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 55°F-85°F setpoint range, 2°F maximum differential, and vented ABS plastic cover.
  - 3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 1 ft section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.
  
- C. Temperature Sensors
  - 1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor (10K).
  - 2. Duct Sensors. Duct sensors shall be single point or averaging. Averaging sensors shall be a minimum of 5 ft in length per 10 ft<sup>2</sup> of duct cross-section.
  - 3. Immersion Sensors. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.
  - 4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port.
  - 5. Differential Sensors. Provide matched sensors for differential temperature measurement.
  
- D. Humidity Sensors
  - 1. Differential Sensors. Provide matched sensors for differential temperature measurement.
  - 2. Duct and room sensors shall have a sensing range of 20%-80%.
  - 3. Duct sensors shall have a sampling chamber.
  - 4. Outdoor air humidity sensors shall have a sensing range of 20%-95% RH and shall be suitable for ambient conditions of 40°F-170°F.
  - 5. Humidity sensors shall not drift more than 1% of full scale annually.
  
- E. Flow Switches. Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service). Switches shall be UL listed, SPDT snap-acting, and pilot duty rated (125 VA minimum).
  - 1. Paddle switches shall have adjustable sensitivity and NEMA 1 enclosure unless otherwise specified.
  - 2. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.
  
- F. Relays
  - 1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
  - 2. Time Delay Relays. Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable  $\pm 100\%$  from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.
  
- G. Override Timers
  - 1. Unless implemented in control software, override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration required by application. Provide 0-6 hour

calibrated dial unless otherwise specified. Flush mount timer on local control panel face or where shown.

H. Current Transmitters

1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be  $\pm 1\%$  full-scale at 500-ohm maximum burden.
2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirement and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.

I. Current Transformers

1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.
2. Transformers shall be available in various current ratios and shall be selected for  $\pm 1\%$  accuracy at 5 A full-scale output.
3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

J. Voltage Transmitters

1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.
2. Adjustable full-scale unit ranges shall be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400- 600 Vac. Unit accuracy shall be  $\pm 1\%$  full-scale at 500-ohm maximum burden.
3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirement and shall be UL/CSA recognized at 600 Vac rating.

K. Voltage Transformers

1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 40°F-130°F and shall provide  $\pm 0.5\%$  accuracy at 24 Vac and 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

L. Power Monitors

1. Power monitors shall be three-phase type and shall have three-phase disconnect and shorting switch assembly, UL listed voltage transformers, and UL listed split-core current transformers.
2. Power monitors shall provide selectable output: rate pulse for kWh reading or 4-20 mA for kW reading. Power monitors shall operate with 5 A current inputs and maximum error of  $\pm 2\%$  at
3. 1.0 power factor or  $\pm 2.5\%$  at 0.5 power factor.

M. Current Switches

1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

N. Pressure Transducers

1. Transducers shall have linear output signal and field-adjustable zero and span.
2. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span shall not damage transducer sensing elements.
3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4-20 mA output, suitable mounting provisions, and block and bleed valves.

4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 150 psi. Over-range limit (differential pressure) and maximum static pressure shall be 300 psi. Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.
- O. Differential Pressure Switches. Differential pressure switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

#### 1.21 NETWORKS

- A. BAS contractor to coordinate with the HFC- IT department for the connections to the 's Network.
- B. Design for the Network LAN (BC LAN) shall include the following provisions:
  1. The network LAN shall utilize BACnet/IP (ASHRAE standard SPC-135A-2004 - Annex L) for communication between BCs. Manufacturer specific proprietary protocols, gateways, or protocol converters are not acceptable for this project. The OWS shall communicate to the BCs utilizing standard Ethernet to IEEE 802.3 Standards.
  2. High-speed data transfer rates for alarm reporting, quick report generation from multiple controllers and upload/download efficiency between network devices.
  3. Detection and accommodation of single or multiple failures of workstations, controller panels and the network media. The network shall include provisions for automatically reconfiguring itself to allow all operational equipment to perform their designated functions as effectively as possible in the event of single or multiple failures.
  4. Message and alarm buffering to prevent information from being lost.
  5. Error detection, correction, and retransmission to guarantee data integrity.
  6. Default device definition to prevent loss of alarms or data, and ensure alarms are reported as quickly as possible in the event an operator device does not respond.
  7. Commonly available, multiple sourced, networking components shall be used to allow the system to coexist with other networking applications such as office automation. ETHERNET is the only acceptable technology.
  8. Synchronization of the real-time clocks in all BC panels shall be provided.
  9. The BC LAN shall be a 100 Megabits/sec Ethernet network supporting BACnet, Java, XML, HTTP, and CORBA IOP for maximum flexibility for integration of building data with enterprise information systems and providing support for multiple Building Controllers (BCs), user workstations and where specified, a local server. Local area network minimum physical and media access requirements:
    - a. Ethernet; IEEE standard 802.3
    - b. Cable; 100 Base-T, UTP-8 wire, category 5
    - c. Minimum throughput; 10 Mbps, with ability to increase to 100 Mbps
  10. Provide access to the BC LAN via a Wireless Application Protocol (WAP) device as well. Through this connection the BC LAN will provide authorized staff with the ability to monitor and control the BAS from any location within the network through a web browser, cellular phone, pager, Web-Pads, or PDA. (Pocket Computer).

#### 1.22 SERVER FUNCTION

- A. Local connections shall be via an Ethernet LAN.
- B. It shall be possible to provide access to all Building Control Units (BC) via a single connection to the server. In this configuration, each Building Control Unit (BC) can be accessed from an Operator Workstation (OWS) using a standard Web browser by connecting to the BAS LAN. The server shall provide the following functions, as a minimum:

1. Global Data Access: The server shall provide complete access to distributed data defined anywhere in the system.
2. Distributed Control: The server shall provide the ability to execute global control strategies based on control and data objects in any Building Control Unit (BC) in the network, local or remote.
3. The server shall include a master clock service for its subsystems and provide time synchronization for all Building Control Units (BC).
4. The server shall accept time synchronization messages from trusted precision Atomic Clock Internet sites and update its master clock based on this data.
5. The server shall provide scheduling for all Building Control Units and their underlying field control devices.
6. The server shall provide demand limiting that operates across all Building Control Units. The server must be capable of multiple demand programs for sites with multiple meters and or multiple sources of energy. Each demand program shall be capable of supporting separate demand shedding lists for effective demand control.
7. The server shall implement the BACnet Command Prioritization scheme (16 levels) for safe and effective contention resolution of all commands issued to Building Control Units. Systems not employing this prioritization shall not be accepted.
8. Each Building Control Unit supported by the server shall have the ability to archive its log data, alarm data and database to the server, automatically. Archiving options shall be user-defined including archive time and archive frequency.
9. The server shall provide central alarm management for all Building Control Units supported by the server. Alarm management shall include:
  10. Routing of alarms to display, printer, email and pagers
  11. View and acknowledge alarms
  12. Query alarm logs based on user-defined parameters
13. The server shall provide central management of log data for all Network Control Units supported by the server. Log data shall include process logs, runtime and event counter logs, audit logs and error logs. Log data management shall include:
  14. Viewing and printing log data
  15. Exporting log data to other software applications
  16. Query log data based on user-defined parameters
17. Minimum BACnet features supported are  
Standard BACnet Objects (Analog In/Out/Value, Binary Input/Output/Value, Multi-State -- Input/Output/Value, Schedule(export), Calendar(export), Trend(Export), Device ).  
Segmented Capability (Segmented Request-Segmented Response).  
Application Services (Read Property, Read Property Multiple, Write Property, Write Property Multiple, Confirmed Event, Notification, Acknowledge Alarm, Get Alarm Summary Who-has, I-have, Who-is, I-am, Subscribe COV, Confirmed COV notification, Unconfirmed COV notification).  
BACnet Broadcast Management

### 1.23 SCOPE OF WORK

- A. The work covered by this specification and related sections consists of providing shop drawings, equipment, labor, materials, engineering, technical supervision, and transportation as required to furnish and install a fully operational BAS to monitor and control the facilities listed herein, and as required to provide the operation specified in strict accordance with these documents, and subject to the terms and conditions of the contract. The work in general consists of but is not limited to, the following:
  1. The preparation of submittals and provision of all related services.
  2. Operator workstations located as listed in the specifications (OWS will be provided by the 's IT, SEE PART 2, SECTION 1.1.4).
  3. Furnish and install all controllers to achieve system operation, any control devices, conduit and wiring, in the facility as required to provide the operation specified.

4. Furnish and load all software required to implement a complete and operational BAS.
5. Furnish complete operating and maintenance manuals and field training of operators, programmers, and maintenance personnel.
6. Perform acceptance tests, commissioning or re-commissioning as indicated.
7. Provide full documentation for all application software and equipment.
8. Miscellaneous work as indicated in these specifications.

#### 1.24 PERMITS, FEES AND CODES

- A. Apply for, obtain and pay for all permits, licenses, inspections, examinations and fees required. Also submit, if required, information and other data that may be obtained from the Engineer. Should the authorities require the information on specific forms, fill in these forms by transcribing the information provided by the Engineer.
- B. BAS contractor shall obtain and pay for the police clearance certificates if required for the project.
- C. Arrange for inspection of all work by the authorities having jurisdiction over the Work. On completion of the Work, present to the Engineer the final unconditional certificate of approval of the inspecting authorities.
- D. Comply with the requirements of the latest edition of the applicable ULC or CSA standards, the requirements of the Authorities, Federal, Provincial/Territorial and Municipal Codes, the applicable standards of ULC and all other authorities having jurisdiction. These Codes and Regulations constitute an integral part of these Specifications.
- E. Where there is no alternative to supply equipment which is CSA certified, submit such equipment to the local electrical authority for special inspection and obtain approval before delivery of equipment to site.
- F. In case of conflict, applicable Codes take precedence over the Contract Documents. In no instance reduce the standard or Scope of Work or intent established by the Drawings and Specifications by applying any of the Codes referred to herein.
- G. Before starting any work, submit the required number of copies of documentation to the authorities for their approval and comments. Comply with any changes requested as part of the Contract, but notify the
- H. Engineer immediately of such changes, for proper processing of these requirements. Prepare and furnish any additional drawings, details or information as may be required.

#### 1.25 COORDINATION

- A. All work shall be performed at times acceptable to the Engineer/Construction Manager. Provide work schedule at the start of the job for the approval of the Engineer/Construction Manager. Schedule shall show when all staff and sub-contractors shall be on-site.
- B. Organize all sub-contractors and ensure that they maintain the schedule.
- C. Full cooperation shall be shown with other sub-contractors to facilitate installations and to avoid delays in carrying out the work.
- D. Notify Engineer/Construction Manager of any changes to the schedule. Send any schedule changes and weekly progress reports via fax to Engineer/Construction Manager.

- E. Where, in the judgment of the Engineer/Construction Manager, the work could disrupt the normal operations in or around the building, contractor shall schedule work to eliminate or minimize interference, subject to owner's approval.
- F. When connecting to the existing systems, advise the Engineer/Construction Manager and obtain permission to so. Perform work at a time acceptable to the Engineer/Construction Manager and Owner.

#### 1.26 SUPERVISION OF PERSONNEL

- A. Maintain at this building qualified personnel and supporting staff with proven experience in erecting, supervising, testing, and adjusting projects of comparable nature and complexity.
- B. Supervisory personnel and their qualifications are subject to the approval of the Owner.
- C. All personnel working on-site shall sign in as required by the Owner and shall wear company identification.
- D. When requested and for whatever reason, remove personnel and/or support staff from project. Take immediate action. Contractors and subcontractors may require police clearance.

#### 1.27 ELECTRICAL WORK AND SAFETY REQUIREMENTS

- A. Control and interlock wiring and installation shall comply with national and local electrical codes, and manufacturer's recommendations.
- B. NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway as specified by NEC.
- C. Low-voltage wiring shall meet NEC Class 2 requirements. Sub fuse low-voltage power circuits as required to meet Class 2 current limit.
- D. NEC Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums shall be UL listed for the intended application.
- E. Install wiring in raceway where subject to mechanical damage and at levels below 10ft in mechanical, electrical, or service rooms.
- F. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high voltage wiring and equipment may not be used for low voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
- G. Install Class 1 and Class 2 wiring in separate raceways. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two through relays and transformers.
- H. Do not install wiring in raceway containing tubing.
- I. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly at 10 ft intervals.
- J. Use structural members to support or anchor plenum cables without raceway. Do not use ductwork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.

- K. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on or attached to ductwork, electrical raceways, piping, or ceiling suspension systems.
- L. Size raceway and select wire size and type in accordance with manufacturer's recommendations and CEC requirements.
- M. Include one pull string in each raceway 1 in. or larger.
- N. Use color-coded conductors throughout.
- O. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.
- P. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 6 in. between raceway and high-temperature equipment such as steam pipes or flues.
- Q. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.
- R. Terminate control and interlock wiring related to the work of this section. Maintain at the job site updated (as-built) wiring diagrams that identify terminations.
- S. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 3 ft in length and shall be supported at each end. Do not use flexible metal raceway less than ½ in. electrical trade size. Use liquid-tight flexible metal raceways in areas exposed to moisture including chiller and boiler rooms.
- T. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.
- U. All equipment and systems installed under this Contract shall be grounded, isolated, or conditioned as required to permit equipment to continue to function normally, without interruption, in the event of radio frequency interference (RFI), electromagnetic interference (EMI), power surges/dips or other electrical anomalies.
- V. It shall be the responsibility of the Contractor or his Sub-contractor to ensure that any coring of holes through the walls or floors will not penetrate existing conduits, cables or mechanical equipment in or under the floor slabs or walls. He shall be responsible to take any and all action as deemed necessary by the Project Manager to correct any such penetrations at his cost. No coring shall be undertaken unless the Project Manager gives permission. Scan walls and floors prior to core drilling to identify hidden piping. Ensure that water does not flow into equipment and below floors. Waterproof and fire stop all penetrations.

#### 1.28 COMMUNICATION WIRING

- A. Communication wiring shall be low-voltage Class 2 wiring.
- B. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.
- C. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.

- D. Verify entire network's integrity following cable installation using appropriate tests for each cable.
- E. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.
- F. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.
- G. Label communication wiring to indicate origination and destination.
- H. Ground coaxial cable according to OEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

1.29 LOCKABLE PANELS

- A. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.
- B. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.
- C. Each local panel shall have a control power source power switch (on-off) with overcurrent protection.

1.30 WARNING LABELS

- A. All Controller panels: Affix permanent warning labels to equipment that can be automatically started by the control system.
  - 1. Labels shall use white lettering (12-point type or larger) on a red background.
  - 2. Warning labels shall read as follows.

**CAUTION**  
**This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to "Off" position before servicing.**

- B. Affix permanent warning labels to motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
  - 1. Labels shall use white lettering (12-point type or larger) on a red background.
  - 2. Warning labels shall read as follows.

**CAUTION**  
**This equipment is fed from more than one power source with separate disconnects.**

1.31 IDENTIFICATION OF HARDWARE AND WIRING

- A. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 2 in. of termination.
- B. Permanently label or code each point of field terminal strips to show instrument or item served.
- C. Label control panels with minimum ½ in. letters on laminated plastic nameplates.

- D. Label each control component with a permanent label. Label plug-in components such that label remains stationary during component replacement.
- E. Label room sensors related to terminal boxes or valves with nameplates.
- F. Manufacturers' nameplates and UL labels shall be visible and legible after equipment is installed.
- G. Label identifiers shall match record documents.
- H. Insert laminated points list in the control panel

#### 1.32 PRELIMINARY DESIGN REVIEW

- A. The BAS contractor shall submit a preliminary design document for review. This document shall contain the following information:
  - 1. Provide a description of the proposed system along with a system architecture diagram with the intention of showing the contractors solution to meet this specification.
  - 2. Provide product data sheets and a technical description of BC, AAC, ASC hardware required to meet specifications listed herein.
  - 3. Provide product brochures and a technical description of the Server, Operator Workstation, and Building Control Unit (BC) software required to meet this specification. Provide a description of software programs included.
  - 4. Open Protocols - For all hardware Building Controllers, Advanced Application Controllers (AAC) and Advanced Specific Controllers (ASC), provide BACnet Interoperability Building Blocks BIBBs certification. Provide complete description and documentation of any proprietary services and/or objects where used in the system.
  - 5. Provide a description and samples of Operator Workstation graphics and reports.
  - 6. Provide an overview of the BAS contractor's local/branch organization, local staff, recent related project experience with references, and local service capabilities.
  - 7. Provide information on the BAS contractors project team including project organization, project manager, project engineer, programmers, project team resumes, and location of staff.

#### 1.33 DRAWING REQUIREMENTS

- A. Within 45 days of award of contract and before start of construction, submit 3 hard copies and 1 soft copy of manufacturers information and shop drawings. Soft copy to be in AutoCAD or VISIO and WordPerfect or Word formats (latest versions) structured using menu format for easy loading and retrieval on the OWS.
- B. Manufacturer's Data: Provide in completely coordinated and indexed package to assure full compliance with the contract requirements. Piecemeal submittal of data is not acceptable and such submittals will be returned without review. Information shall be submitted for all material and equipment the contractor proposes to furnish under terms of this contract work. Arrange the
- C. submittals in the same sequence as these specifications and reference at the upper right-hand corner the particular specification provision for which each submittal is intended. Submittals for each manufactured item shall be manufacturer's descriptive literature (equipment specification), equipment drawings, diagrams, performance and characteristic curves, and catalog cuts, and shall include the manufacturer's name, trade name, catalog model or number, nameplate data, size layout dimension, capacity, specification reference, applicable specification references, and all other information necessary to establish contract compliance.
- D. Shop drawings: Provide in completely coordinated and indexed package:

1. Wiring and piping diagrams.
2. Control schematics with narrative description and control descriptive logic fully showing and describing operation and/or manual procedures available to operating personnel to achieve proper operation of the building, including under complete failure of the BAS.
3. Shop drawings for each input/output point showing all information associated with each particular point including sensing element type and location; details of associated field wiring schematics and schedules; point address; software and programming details (CDL's) associated with each point; and manufacturer's recommended installation instructions and procedures for each type of sensor and/or transmitter.
4. Detailed system architecture showing all points associated with each controller, controller locations, and describing the spare points capacity at each controller and BAS LAN.
5. Each BC shall contain a minimum of 20% spare resource capacity. The BC shall provide a throughput capable of transmitting all BAS LAN data connected to it within 10 seconds.
6. Each AAC and ASC shall have a minimum of 15% spare capacity for each point type for future point connection. Provide all processors, power supplies and communication controllers complete so that the implementation of a point only requires the addition of the appropriate point input/output termination module and wiring. As a minimum, provide one of each type of point available on the controller.
7. Specification sheets for each item including manufacturers descriptive literature, drawings, diagrams, performance and characteristic curves, manufacturer and model number, size, layout, dimensions, capacity, etc
8. Color graphic displays detailing hierarchical structure of facility, including floor plans, with multi-level penetration to equipment level.

#### 1.34 START-UP AND CHECKOUT

- A. This work shall include field testing and adjustment of the complete BAS, and on-site final operational acceptance test of the complete operational BAS. The Engineer shall be advised at least 14 days in advance of the dates of all tests and may attend at his discretion. If the Engineer witnesses the test, such tests shall be subject to his approval prior to the release of equipment. If the Engineer elects not to witness the tests, the contractor shall provide performance certification. Acceptance of tests by the Engineer and Project Manager shall not relieve the contractor of responsibility for the complete system meeting the requirements of these specifications after installation.
- B. Static testing:
  1. Static testing shall include point-by-point testing of the entire system and completion of Component Test Sheets. The contractor shall forward proposed Test Sheets at the shop drawing review stage. These Component Test Sheets shall be completed during the contractor's own testing and verification procedure that is done prior to the request for a final inspection. The completed Component Test Sheets shall then be returned to the Engineer for review and approval. The Engineer may repeat a random sampling of at least 50% of the tests during the Engineers commissioning procedure to corroborate their accuracy. The Contractor shall be on site with test equipment during this verification process. The test procedures shall include the following.
    - a. Digital input component test sheet:
    - b. DI status shall be verified at the POT and OWS for ON and OFF status.
    - c. All digital alarm inputs shall be proven using actual field conditions where possible or be jumped at the field device for testing with the approval of the Engineer.
  2. Digital output component test sheet:
    - a. Status to be verified at the equipment location. Verification at the OWS shall be completed for ON and OFF status, software DISABLE indicator and OVERRIDEN indicator
  3. Analog input component test sheet:

- a. All temperature sensors shall be calibrated using a handheld meter with equal or better accuracy.
  - b. Selected temperature sensors chosen by the Engineer shall be verified by spraying with a cold spray or other means to ensure response and to test the low temperature alarm condition.
  - c. All pressure sensing devices and analog output feedback shall be verified using a device with equal or better accuracy to ensure correct calibration.
  - d. All humidity sensing devices must be verified using a recently calibrated device with equal or better accuracy
  - e. All CTs shall be set to accurately reflect motor status, including removing belts on belt driven equipment
  - f. All other devices shall be verified using appropriate devices of equal or better accuracy
  - g. Adjust span on feedback devices so that input matches the end device
4. Analog output component test sheet:
- a. All points shall be tested by sending a command from the PWS or OWS to incrementally stroke the field device from full CLOSED to full OPEN and measuring the signal at the field device. The increments of the test shall be no larger than 10% of the output span.
  - b. The AO feedback requirement shall also be tested by failing the field device and verifying that the alarm registers
  - c. Each output shall be exercised over the full output capability of the panel
  - d. Field device hysteresis shall be measured at a minimum of three output levels for each direction of travel. Output increments shall not exceed 2% of span for this test

#### 1.35 STANDARDS COMPLIANCE

- A. Where materials or equipment are specified to conform to requirements of the standards of organizations, such as the Canadian Standards Association (CSA) that use a label or listing as method of indicating compliance, proof of such conformance shall be submitted and approved, indexed and cross-referenced with the specification. The label or listing of the specified organization will be acceptable evidence. In lieu of the label or listing, the contractor shall submit a certificate from a testing organization adequately equipped and competent to perform such services, and approved by the Engineer, stating that the item has been tested in accordance with the specified organization's test methods and that the item conforms to the specified organization's standard or code. For materials whose compliance with organizational standards or specifications is not regulated by an organization using its own listing or label as proof of compliance, a certificate from the manufacturer shall be furnished to the Engineer stating that the material complies with the applicable referenced standard or specification.

#### 1.36 FINAL ACCEPTANCE

- A. Final acceptance shall commence only after satisfactory completion of start-up, verification of performance and the 30-day test period described earlier. When the Contractor has satisfied himself as to proper system operation he shall advise the BAS Commissioning Engineer/Consultant to establish a date for Final Acceptance. This will involve a point-by-point check of all hardware and software items including graphics and displayed data, as well as performing tasks as directed.
- B. Supply 2-way radios and all test equipment as previously specified. Have on-site technical personnel capable of re-calibrating all field hardware and modifying software.

- C. Test each system independently and then in unison with other related systems. Test weather sensitive systems twice- once near winter design conditions and again near summer design conditions.
- D. Optimize operation and performance of each system. Test full-scale emergency operation and integrity of smoke management and other life safety systems.
- E. Demonstrate to the Engineer the operation of each system including sequence of operations in regular and emergency modes, under all normal and emergency conditions, start-up, shut-down, interlocks, and lock- outs.
- F. Upon completion of the testing submit a report to the Engineer to summarize all testing.

#### 1.37 DOCUMENTATION

- A. Documentation shall consist of 4 hard copies and one soft copy for all information described below
- B. The final documentation package shall include:
  - 1. Hard and soft copies of all control drawings (As-Builts).
  - 2. Manufacturer's technical data sheets for all hardware and software
  - 3. Factory operating and maintenance manuals with any customization required
  - 4. Soft copies of programming and front-end software and each controller's database. Hard copy output of programming is not necessary
  - 5. Provide clear, concise, typewritten and soft copy descriptions of all control sequences in the working language.
  - 6. Soft copy text files shall be in MS-Word.
- C. Each instruction and reference manual shall be bound in hardback, 3 ring, binders or an approved equivalent shall be provided to the Engineer. Binders to be no more than 2/3 full. Each binder to contain index to full volume. One complete set of manuals shall be furnished prior to the time that the system or equipment tests are performed, and the remaining manuals shall be furnished at acceptance. The identification of each manual's contents shall be inscribed on the cover and spine. The manuals shall include the names, addresses and telephone numbers of each subcontractor installing equipment systems and of the local representatives for each item of equipment and each system. The manuals shall have a table of contents and be assembled to conform to the table of contents with the tab sheets placed before instructions covering the subject. Additionally, each manual shall contain a comprehensive index of all manuals submitted in accordance with this paragraph. Manuals and specifications shall be furnished which provide full and complete coverage of the following subjects:
- D. Operational Requirements: This document shall describe in concise terms, all the functional and operational requirements for the system and its functions that have been implemented. It shall be written using common terminology for building operation staff and shall not presume knowledge of digital computers, electronics or in-depth control theory.
- E. System Operation: Complete step by step procedures for operation of the system, including required actions at each operator station; operation of computer peripherals; input and output formats; and emergency, alarm and failure recovery. Step-by-step instructions for system startup, back-up equipment operation, and execution of all system functions and operating modes shall be provided.
- F. Maintenance: Documentation of all maintenance procedures for all system components including inspection, periodic preventive maintenance, fault diagnosis, and repair or replacement of defective module. This shall include calibration, maintenance, and repair or replacement of all system hardware.

- G. Test Procedures and Reports: The test implementation shall be recorded with a description of the test exercise script of events and documented as test procedures. A provision for the measurement or observation of results, based on the previously published test specification, forms the test reports. The procedures record and the results of these exercises shall be conveniently bound and documented together.
- H. Configuration Control: Documentation of the basic system design and configuration with provisions and procedures for planning, implementing, and recording any hardware or software modifications required during the installation, test, and operating lifetime of the system. This shall include all information required to ensure necessary coordination of hardware and software changes, data link or message format/content changes, and sensor or control changes in the event system modification are required, and to fully document such new system configurations.

### 1.38 TRAINING

- A. The Contractor shall provide the services of competent instructors who will provide instruction to designated personnel in the adjustment, operation and maintenance, including pertinent safety requirements, of the equipment and system specified. The training shall be oriented towards the system installed rather than being a general "canned" training course. Instructors shall be thoroughly familiar with all aspects of the subject matter they are to teach. The number of person-days (eight hours) of instruction furnished shall be as specified below as a minimum. A training manual shall be provided for each trainee that describes in detail the data included in each training program.
- B. All equipment and material required for classroom training shall be provided by the contractor. A person- week shall be considered as 26.5 hours, 8:00 am to 12:00 noon, and 12:30 pm to 4:30 pm Monday through Friday. Provide 3 days of training as specified herein.
- C. Training shall enable operators to accomplish the following objectives:
  - 1. Proficiently operate system
  - 2. Understand control system design and configuration
  - 3. Create and change system graphics
  - 4. Create, delete, and modify alarms, including configuring alarm reactions
  - 5. Configure and run reports
  - 6. Add, remove, and modify system's physical points
  - 7. Create, modify, and delete application programming
  - 8. Add a new controller to system
  - 9. Download firmware and advanced applications programming to a controller
  - 10. Configure and calibrate I/O points
  - 11. Maintain software and prepare backups
  - 12. Understand DDC system components
  - 13. Understand system operation, including DDC system control and optimizing routines (algorithms)
  - 14. Operate workstation and peripherals
  - 15. Log on and off system
  - 16. Access graphics, point reports, and logs
  - 17. Adjust and change system setpoints, time schedules, and holiday schedules
  - 18. Recognize common HVAC system malfunctions by observing system graphics, trend graphs, and other system tools
  - 19. Access data from DDC controllers
  - 20. Add new users and understand password security procedures

1.39 WARRANTY

- A. Provide warranty certificates showing the name of the firm giving the warranty, dated from the issuance of the Certificate of Substantial Performance and acknowledged on specific equipment and systems.
- B. Include these certificates with the Operation and Maintenance Manual in the appropriate sections.
- C. Contractor shall give a minimum two-year warranty for parts and labor on all equipment and materials installed and shall select materials and equipment where the Manufacturer gives the same warranty arrangements. Warranty shall commence on the date of the Engineers issuance of the Certificate of Substantial Completion.
- D. Provide a warranty as indicated in 38.0 - Maintenance/Service.
- E. The Contractor shall agree to make good at his own expense any equipment that fails to operate due to poor workmanship, manufacturing defect or improper installation. Any repairs shall be made at the convenience of the Engineer during normal working hours, unless deemed an emergency.
- F. Provide upgrades to all software or all panel firmware issued during the warranty period at no charge to Owner.

1.40 MAINTENANCE / SERVICE

- A. Provide warranty in accordance with the warranty section of this specification. In addition, provide scheduled maintenance and service during the warranty period on all control system apparatus including but not limited to valves, dampers, linkages, control panels, interfaces, direct digital control systems, OWS, Server, BC, AAC, ASC, Software and application programs.
- B. Scheduled preventive maintenance inspections will provide those services required to maintain the system at maximum performance and reliability levels and may include the following:
- C. Analyze, adjust, calibrate the applicable temperature sensors, humidity sensors, diagnostic LEDs, printers, power supplies, workstations, controllers, modems, input/output points, communication cabling, transmitters, transducers, UPS for the BAS system.
- D. Conduct inspections and thorough preventive maintenance routine on each piece of covered equipment. In addition, make tests and adjustments to ensure efficient and reliable operation of other major components.
- E. Examine, clean and calibrate as required sensors, thermostats, humidity controls, temperature controls, pressure controls, relays, damper actuators, instrumentation and accessories directly pertaining to the Building Automation System.
- F. Check and confirm control system sequence of operation to insure optimum system efficiency and economy.
- G. A log of each loop tested, and each control sequence verified shall be reviewed with the owner.
- H. All components of the Pneumatics Control System will be serviced according to manufacturer's recommendations during each year of the contract. This will include (but not be limited to) all lubricant changes, filter changes, adjustments, calibrations and cleaning.

- I. The system includes, but is not limited to, the air compressor, air receiver, pressure reducing valves, air dryers and all sensors, controllers, transducers, damper and valve operators, thermostats, pilot positioners, electro-pneumatic switches, linkages and any other pneumatic and electronic devices used to maintain the environmental comfort in the building.
- J. The Contractor will provide preventative maintenance and diagnostic inspections to all electronic system components on a frequency established by manufacturer's recommendations, component age and condition and discussion with the Supervisor of Operations responsible for the site.
- K. Provide a fully trained BAS service technician and a Pneumatic fitter (Required for Pneumatic/DDC system) a minimum of one day per month (8 hours for DDC technician and 8 hours for pneumatic fitter) during the warranty period to provide the preventive maintenance and service described above. Provide written reports to the owner outlining the work performed. Allow for 6 annual visits of one day each (12 days total for 2 years) during the warranty period to provide required service..
- L. Provide emergency service for parts and labor on an as needed basis. Response to an emergency call shall be 2 hours maximum on Mon.-Fri. including on holidays and weekends.
- M. Provide remote service diagnostic monitoring from the local office. At the request of the owner, a service diagnostic call will be made to troubleshoot and resolve (if possible) any reported system complaints.
- N. Provide a price for a three-year service agreement based on the above requirements to come in to effect upon the completion of the warranty period. Show this price as OPTION: Service Agreement.

## **PART 2 - OPERATOR WORKSTATION (OWS) AND SOFTWARE**

### **2.1 GENERAL**

- A. General Requirements: Section 23 09 23 BUILDING AUTOMATION SYSTEM (BAS)
- B. Performance requirements of the Operator WorkStation (OWS) and the Graphical Users Interface are specified in this section.
- C. Environmental Conditions: The OWS and its immediate associated devices shall be able to operate properly under environmental conditions of 40 deg F to 90 deg F and a relative humidity of 20 to 90% non-condensing.
- D. OWS shall be provided by the Owners's IT department. BAS contractor shall NOT include the cost of the computer for the pricing of the project. The OWS shall be provided for centralized system control, information management, alarm management and data base management functions. All real time control functions shall be resident in the standalone Building Control Unit (BC) and local controllers (AACs and ASCs).
- E. Provide two copies of all Programming Software; one each for OWS and a laptop;
- F. Any computer on the BAS LAN shall be capable of displaying the systems in a graphical and dynamic format utilizing a standard web browser. Screen refresh shall be automatic. Manual refresh is not acceptable.

## 2.2 WORKSTATION HARDWARE REQUIREMENTS

- A. Reference 1.1.5
- B. BAS contractor shall coordinate with the 's IT department through the project manager to discuss minimum requirement of the workstation's (computer) hardware, software (operating system) to ensure BAS system will meet or exceed the performance requirement of this specifications.
- C. Connection to the BAS LAN network shall be via an Ethernet network interface card, 100 Mbps.
- D. Provide 2 Workstations. The Workstation(s) will be located as directed by the engineer.
- E. Hardware Base. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications. Hard disk shall have sufficient memory to store system software, one year of data for trended points specified by the sequence of operation and the points list. Workstations shall be with a minimum of:
  - 1. Intel Pentium 2.66 GHz processor (Pentium IV- Duo Core)
  - 2. 16 GB RAM
  - 3. 80 GB hard disk providing data at 100 MB/sec
  - 4. 48x CD-ROM drive
  - 5. Keyboard
  - 6. Mouse
  - 7. Dual 24-inch 24-bit color monitor with at least 1024 x 768 resolution
  - 8. Serial, parallel, and network communication ports and cables required for proper system operation

## 2.3 PRINTERS

- A. BAS contractor to coordinate with the 's IT department through the project manager to ensure a network printer is connected to the Operator Workstation that is provided by the 's IT department.
- B. If the site doesn't have a printer available, then 's IT department shall provide a desktop printer.
- C. Printer Specifications- For Guidance only: The printer shall be at least an inkjet printer, 1440 x1440 dpi resolution, internal 1MB buffer memory, minimum 8 ppm in black. No color printer is required.

## 2.4 UNINTERRUPTABLE POWER SUPPLIES

- A. Provide the OWS, Server (if applicable), and each BC with individual UPS to provide clean, reliable, noise- filtered power at all times and to protect and maintain systems operation throughout short term power interruptions of up to 15 minutes duration. (site specific)
- B. BAS contractor shall also coordinate with building engineer what it would take to have the OWS on backup power.

## 2.5 PROGRAMMING SOFTWARE

- A. Custom Application Programming. Operator shall be able to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:
  - 1. Language. Language shall be graphically based or English language oriented. If graphically based, language shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed

- below, and operators shall be able to create custom or compound function blocks and shall allow for free-form programming that is not column-oriented or "fill-in-the-blanks."
2. Programming Environment. Tool shall provide a full-screen, cursor-and-mouse-driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.
  3. Independent Program Modules. Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.
  4. Debugging and Simulation. Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.
  5. Conditional Statements. Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
  6. Mathematical Functions. Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.
  7. Variables: Operator shall be able to use variable values in program conditional statements and mathematical functions.
    - a. Time Variables. Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.
    - b. System Variables. Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.
- B. The software shall provide the ability to perform system programming and graphic display engineering as part of a complete software package. Access to the programming functions and features of the software shall be through password access as assigned by the system administrator.
- C. Demand Limiting Object. Provide a comprehensive demand-limiting object that is capable of controlling demand for any selected energy utility (electric, oil, and gas). The object shall provide the capability of monitoring a demand value and predicting (by use of a sliding window prediction algorithm) the demand at the end of the user defined interval period (1-60 minutes). This object shall also accommodate a utility meter time sync pulse for fixed interval demand control. Upon a prediction that will exceed the user defined demand limit (supply a minimum of 6 per day), the demand limiting object shall issue shed commands to either turn off user specified loads or modify equipment set points to effect the desired energy reduction. If the list of equipment is not enough to reduce the demand to below the set point, a message shall be displayed on the users screen (as an alarm) instructing the user to take manual actions to maintain the desired demand. The shed lists are specified by the user and shall be selectable to be shed in either a fixed or rotating order to control which equipment is shed the most often. Upon suitable reductions in demand, the demand-limiting object shall restore the equipment that was shed in the reverse order in which it was shed. Each shed-able object shall have a minimum and maximum shed time property to effect both equipment protection and occupant comfort.
- D. Start-Stop Time Optimization Object. Provide a start-stop time optimization object to provide the capability of starting equipment just early enough to bring space conditions to desired conditions by the scheduled occupancy time. Also, allow equipment to be stopped before the scheduled un-occupancy time just far enough ahead to take advantage of the building's flywheel effect for

energy savings. Provide automatic tuning of all start / stop time object properties based on the previous day's performance.

- E. A library of control, application, and graphic objects shall be provided to enable the creation of all applications and user interface screens. Applications are to be created by selecting the desired control objects from the library, dragging or pasting them on the screen, and linking them together using a built in graphical connection tool. Completed applications may be stored in the library for future use. Graphical User Interface screens shall be created in the same fashion. Data for the user displays is obtained by graphically linking the user display objects to the application objects to provide real-time data updates. Any real-time data value or object property may be connected to display its current value on a user display Systems requiring separate software tools or processes to create applications and user interface displays shall not be acceptable.
1. Programming Methods
    - a. Provide the capability to copy objects from the supplied libraries, or from a user-defined library to the user's application. Objects shall be linked by a graphical linking scheme by dragging a link from one object to another. Object links will support one-to-one, many-to-one, or one-to-many relationships. Linked objects shall maintain their connections to other objects regardless of where they are positioned on the page and shall show link identification for links to objects on other pages for easy identification. Links will vary in color depending on the type of link; i.e., internal, external, hardware, etc.
    - b. Configuration of each object will be done through the object's property sheet using fill-in the blank fields, list boxes, and selection buttons. Use of custom programming, scripting language, or a manufacturer-specific procedural language for configuration will not be accepted.
    - c. The software shall provide the ability to view the logic in a monitor mode. When on-line, the monitor mode shall provide the ability to view the logic in real time for easy diagnosis of the logic execution. When off-line (debug), the monitor mode shall allow the user to set values to inputs and monitor the logic for diagnosing execution before it is applied to the system.
    - d. All programming shall be done in real-time. Systems requiring the uploading, editing, and downloading of database objects shall not be allowed.
    - e. The system shall support object duplication within a customer's database. An application, once configured, can be copied and pasted for easy re-use and duplication. All links, other than to the hardware, shall be maintained during duplication.
    - f. The user shall be able to pick a graphical function block from the menu and place on the screen. Programming tools shall place lines connecting appropriate function blocks together automatically. Provide zoom in and zoom out capabilities. Function blocks shall be downloaded to controller without any reentry of data.
    - g. The programming tools shall include a test mode. Test mode shall show user real-time data on top of graphical display of selected function blocks. Data shall be updated real-time with no interaction by the user. Function blocks shall be animated to show status of data inputs and outputs. Animation shall show change of status on logic devices and countdown of timer devices in graphical format.
    - h. Composite Object - Provide a container object that allows a collection of objects representing an application to be encapsulated to protect the application from tampering, or to more easily represent large applications. This object must have the ability to allow the user to select the appropriate parameters of the contained application that are represented on the graphical shell of this container.

## 2.6 OPERATOR WORKSTATION SOFTWARE

- A. Operating System: 's IT department will provide OWS including operating system.

- B. The BAS software shall employ browser-like functionality for ease of navigation. It shall include a tree view (similar to Windows Explorer) for quick viewing of, and access to, the hierarchical structure of the database. In addition, menu-pull downs, and toolbars shall employ buttons, commands and navigation to permit the operator to perform tasks with a minimum knowledge of the HVAC Control System and basic computing skills. These shall include, but are not limited to, forward/backward buttons, home button, and a context sensitive locator line (similar to a URL line), that displays the location and the selected object identification.
- C. Real-Time Displays. The OWS, shall at a minimum, support the following graphical features and functions:
  - 1. Graphic screens shall be developed using any drawing package capable of generating a GIF, BMP, or JPG file format. Use of proprietary graphic file formats shall not be acceptable. In addition to, or in lieu of a graphic background, the GUI shall support the use of scanned pictures.
  - 2. Graphic screens shall have the capability to contain objects for text, real-time values, animation, colour spectrum objects, logs, graphs, HTML or XML document links, schedule objects, hyperlinks to other URLs, and links to other graphic screens.
  - 3. Graphics shall support layering and each graphic object shall be configurable for assignment to one a layer. A minimum of six layers shall be supported.
- D. Modifying common application objects, such as schedules, calendars, and set points shall be accomplished in a graphical manner. Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator. Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.
- E. Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
- F. Right-clicking the selected object and using a graphical slider to adjust the value shall make adjustments to analog objects, such as set points. No entry of text shall be required.
- G. System Configuration. At a minimum, the OWS shall permit the operator to perform the following tasks, with proper password access:
  - 1. Create, delete or modify control strategies.
  - 2. Add/delete objects to the system.
  - 3. Tune control loops through the adjustment of control loop parameters.
  - 4. Enable or disable control strategies.
  - 5. Generate hard copy records or control strategies on a printer.
  - 6. Select points to be alarm-able and define the alarm state.
  - 7. Select points to be trended over a period of time and initiate the recording of values automatically.
- H. On-Line Help. Provide a context sensitive, on-line help system to assist the operator in operation and editing of the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext. All system documentation and help files shall be in HTML format.
- I. Security. Each operator shall be required to log on to that system with a user name and password in order to view, edit add, or delete data. System security shall be selectable for each operator. The system administrator shall have the ability to set passwords and security levels for all other operators. Each operator password shall be able to restrict the operators' access for viewing and/or changing each system application, full screen editor, and object. Each operator shall automatically be logged off of the system if no keyboard or mouse activity is detected. This auto log-off time shall be set per operator password. All system security data shall be stored in an encrypted format.

- J. System Diagnostics. The system shall automatically monitor the operation of all workstations, printers, modems, network connections, building management panels, and controllers. The failure of any device shall be annunciated to the operator.
- K. Alarm Console. The system shall be provided with a dedicated alarm window or console. This window will notify the operator of an alarm condition and allow the operator to view details of the alarm and acknowledge the alarm. The use of the Alarm Console can be enabled or disabled by the system administrator. When the Alarm Console is enabled, a separate alarm notification window will supersede all other windows on the desktop and shall not be capable of being minimized or closed by the operator. This window will notify the operator of new alarms and un-acknowledged alarms. Alarm notification windows or banners that can be minimized or closed by the operator shall not be acceptable.
- L. Operator's workstation software shall contain an easy-to-operate system; allowing configuration of system-wide controllers, including management and display of the controller programming. This system shall provide the capability to configure controller binary and analog inputs/outputs.
- M. The system shall be capable of utilizing third-party Windows-based programs for such things as spreadsheet analysis, graphing, charting, custom report generation, and graphics design packages. Graphics generation shall be done using standard Windows packages. No proprietary graphics generation software shall be needed.
- N. Provide software, which enables the non-programmer operator to easily perform, tasks which are likely to be part of his daily routine.
- O. The operator's console shall provide facilities for manual entries and visual displays enabling an operator to enter information into the system and obtain displays and logs of system information. All requests for status, analog, graphic displays, logs, and control shall be selected from the operator's console. The operator interface shall minimize the use of typewriter style keyboard by implementing a mouse or similar pointing device and "point and click" approach to command selection. The facility shall be provided to permit the operator to perform the following tasks:
  - 1. Automatic logging of digital alarms and change of status message.
  - 2. Automatic logging of all analog alarms.
  - 3. System changes (alarm limits, set-points, alarm lock-outs, etc.).
  - 4. Display specific points as requested by the operator.
  - 5. Provide reports as requested by the operator and on Scheduled basis where so required.
  - 6. Display graphics as requested by the operator.
  - 7. Display help information.
  - 8. Provide trend logs as required by the operator.
  - 9. Provide manual control of digital and analog outputs as required by the operator.
  - 10. Direct the hard copy output of information to the device selected by the operator.
  - 11. Data displayed on monitor to cyclic update as appropriate.
- P. Online changes
  - 1. Alarm limits
  - 2. Setpoints
  - 3. Dead bands
  - 4. Changes/deletions/additions of points.
  - 5. Control and change of state changes.
  - 6. Time of day, day, month, year.
  - 7. Control loop control description changes for NCU based CDM's.
  - 8. Control loop tuning changes
  - 9. Schedule changes
  - 10. Changes/additions/deletions to system graphics
  - 11. Changes/additions/deletions to total systems

- Q. It shall be possible for the OWS operator to initiate analog and digital output commands. Where the BAS software normally originates these outputs, the provision shall exist for the operator to terminate automatic BAS control of any particular output and to originate a manual analog or digital output command. The provision shall exist for the operator to return analog or digital output command functions to automatic BAS software control.
- R. It shall be possible for the OWS operator to place any computed system setpoint to a computed basis or manual value as and when required.
- S. All above functions shall operate under the password protection system.
- T. A vocabulary of at least 25 different descriptions using at least six alphanumeric characters to identify engineering units for analog input and output points. Typical description is as follows: %, Deg.C, KPA, KW, KWH, L/S, CFM, Deg.F, PSI. The descriptions shall be alterable from the OWS console with the system on-line.
- U. Upon operator's request, the system shall present the condition of any single point, any system, and area or the whole system on printer or CRT. The output device shall be by operator's choice. Analog values and status displayed on the CRT shall be updated whenever new values are received. Points in alarm shall be flagged by blinking, inverse video different colour, bracketed, or by some other means to differentiate them from points not in alarm.

2.7 REPORTING ACCURACY

- A. System shall report values with minimum end-to-end accuracy listed in Table 1.

2.8 CONTROL STABILITY AND ACCURACY

- A. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

Table 1  
**Reporting Accuracy**

Measured Variable	Reported Accuracy
Space Temperature	±1°F
Ducted Air	±1°F
Outside Air	±2°F
Dew Point	±3°F
Water Temperature	±1°F
Delta-T	±0.25°F
Relative Humidity	±5% RH
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±0.1 in. w.g
Air Pressure (space)	±0.01 in. w.g.
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)

**Note 1: 10% - 100% of scale**

**Note 2: For both absolute and differential pressure**

**Note 3: Not including utility-supplied meters**

**Table 2  
Control Stability and Accuracy**

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±0.2 in. w.g. ±0.01 in. w.g.	0-6 in. w.g. -0.1 to 0.1 in. w.g.
Airflow	±10% of full scale	
Space Temperature	±2.0°F	
Duct Temperature	±3°F	

2.9 ERROR MESSAGE

- A. Inform operator of all errors in data, errors in entry instructions, failure of equipment to respond to requests or commands, or failure of communications between components of EMCS.
- B. Error messages to be comprehensive and communicate clearly to operator precise nature of problem.

2.10 PASSWORD PROTECTION

- A. Provide security system that prevents unauthorized use unless operator is logged on. Access shall be limited to operator’s terminal functions unless user is logged on. This includes displays as outlined above.
- B. Each user shall have an individual User ID, User Name and Password. Entries are alphanumeric characters only and are case sensitive (except for User ID). User ID shall be 8 characters, User Name shall be 29 characters, and Password shall be 8 characters long. Each system user shall be allowed individual assignment of only those control functions and menu items to which that user requires access. All passwords, user names, and access assignments shall be adjustable online at the operator’s terminal. Each user shall also have a set security level, which defines access to displays and individual objects the user may control. System shall include 10 separate and distinct security levels for assignment to users.

2.11 AUDIT LOGS

- A. Provide and maintain an Audit Log that tracks all activities performed on the NCU. Provide the ability to specify a buffer size for the log and the ability to archive log based on time or when the log has reached it=s user-defined buffer size. Provide the ability to archive the log locally (to the NCU), to another NCU on the network, or to a server. For each log entry, provide the following data:
  - B. Time and date
  - C. User ID
  - D. Change or activity: i.e., Change setpoint, add or delete objects, commands, etc.

## 2.12 TREND DATA

- A. System shall periodically gather historically recorded selected samples of object data stored in the field equipment (global controllers, field controllers) and archive the information on the operator's workstation (server) hard disk. Archived files shall be appended with new sample data, allowing samples to be accumulated over several years. Systems that write over archived data shall not be allowed, unless limited file size is specified. Samples may be viewed at the operator's terminal in a trendlog. Logged data shall be stored in spreadsheet format. Operator shall be able to scroll through all trendlog data. System shall automatically open archive files as needed to display archived data when operator scrolls through the data vertically. All trendlog information shall be displayed in standard engineering units.
- B. Software shall be included that is capable of graphing the trend logged object data. Software shall be capable of creating two-axis (x,y) graphs that display up to six object types at the same time in different colors. Graphs shall show object type value relative to time.
- C. Operator shall be able to change trend log setup information. This includes the information to be logged as well as the interval at which it is to be logged. All input, output, and value object types in the system may be logged. All operations shall be password protected. Setup and viewing may be accessed directly from any and all graphics on which object is displayed.
- D. System shall be capable of periodically gathering energy log data stored in the field equipment and archive the information on the operator workstation's hard disk. Log data shall include both instantaneous and accumulated values. Archive files shall be appended with the new data, allowing data to be accumulated over several years. Systems that write over archived data shall not be allowed unless limited file size is specified. System shall automatically open archive files as needed to display archived data when operator scrolls through the data. Display all energy log information in standard engineering units.
- E. System software shall be provided that is capable of graphing the energy log data. Software shall be capable of creating two-axis (x,y) graph that show recorded data, relative to time. All data shall be stored in comma-delimited file format for direct use by third-party spreadsheet or other database programs. Operation of system shall not be affected by this operation. In other words, it shall stay completely online.
- F. Operator shall be able to change the energy log setup information as well. This includes the meters to be logged, meter pulse value, and the type of energy units to be logged. All meters monitored by the system may be logged. All operations shall be password protected.

## 2.13 GRAPHICS

- A. The operator's workstation shall display all data associated with the project. The operator's terminal software shall accept Windows BITMAP (\*.bmp) format graphic files for display purposes. Graphic files shall be created using scanned, full color photographs of system installation, AutoCAD drawing files of field installation drawings and wiring diagrams from as-built drawings. Operator's terminal shall display all data using 3-D graphic representations of all mechanical equipment.
- B. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 seconds.
- C. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 seconds and shall automatically refresh every 15 seconds

- D. Color graphic displays detailing hierarchical structure of facility, including floor plans, with multi-level penetration to equipment level.
- E. System shall be capable of displaying graphic file, text, and dynamic object data together on each display. Information shall be labelled with descriptors and shall be shown with the appropriate engineering units. All information on any display shall be dynamically updated without any action by the user. Terminal shall allow user to change all field-resident BAS functions associated with the project, such as setpoints, weekly schedules, exception schedules, etc. from any screen no matter if that screen shows all text or a complete graphic display. This shall be done without any reference to object addresses or other numeric/mnemonic indications.
- F. All displays shall be generated and customized in such a manner that they fit the project as specified. Canned displays shall not be acceptable. Displays shall use standard English for labelling and readout. Systems requiring factory programming for graphics or DDC logic are specifically prohibited. The installing contractor without factory dependency or assistance shall support all graphics and DDC programming locally.
- G. Binary objects shall be displayed as ON/OFF/NULL or with customized text. Text shall be justified left, right or centre as selected by the user. Also, allow binary objects to be displayed as individual change-of-state bitmap objects on the display screen such that they overlay the system graphic. Each binary object displayed in this manner shall be assigned up to three bitmap files for display when the point is ON, OFF or in alarm. For binary outputs, toggle the objects commanded status when the bitmap is selected with the system digitizer (mouse). Similarly, allow the terminal operator to toggle the object's status by selecting (with the mouse) a picture of a switch or light, for example, which then displays a different picture (such as an ON switch or lighted lamp). Additionally, allow binary objects to be displayed as an animated graphic.
- H. Animated graphic objects shall be displayed as a sequence of multiple bitmaps to simulate motion. For example: when a pump is in the OFF condition, display a stationary picture of the pump. When the operator selects the pump picture with the mouse, the represented objects status is toggled and the picture of the pumps impeller rotates in a time-based animation. The operator shall be able to click on an animated graphical object or switch it from the OFF position to ON, or ON to OFF. Allow operator to change bitmap file assignment and also create new and original bitmaps online. System shall be supplied with a library of standard bitmaps, which may be used unaltered or modified by the operator. Systems that do not allow customization or creation of new bitmap objects by the operator (or with third-party software) shall not be allowed.
- I. Analog objects shall be displayed with operator modifiable units. Analog input objects may also be displayed as individual bitmap items on the display screen as an overlay to the system graphic. Each analog input object may be assigned to a minimum of five bitmap files, each with high/low limits for automatic selection and display of the bitmaps. As an example, a graphic representation of a thermometer would rise and fall in response to either the room temperature or its deviation from the controlling setpoint. Analog output objects, when selected with the mouse, shall be displayed as a prompted dialog (text only) box. Selection for display type shall be individual for each object. Analog object values may be changed by selecting either the increase or decrease arrow in the analog object spinner box without using the keypad. Pressing the button on the right side of the analog object spinner box allows direct entry of an analog value and accesses various menus where the analog value may be used, such as trend logs.
- J. Analog objects may also be assigned to an area of a system graphic, where the color of the defined area would change based on the analog objects value. For example, an area of a floor-plan graphic served by a single control zone would change color with respect to the temperature of the zone or its deviation from setpoint. All editing and area assignment shall be created or modified online using simple icon tools.

- K. A customized menu label (push-button) shall be used for display selection. Menu items on a display shall allow penetration to lower level displays or additional menus. Dynamic point information and menu label push buttons may be mixed on the same display to allow sub-displays to exist for each item. Each display may be protected from viewing unless operator has appropriate security level. A separate security level may be assigned to each display and system object.
- L. A mouse, or other form of digitizer, shall be used to move the pointer arrow to the desired item for selection of new display or to allow the operator to make changes to object data.
- M. Displays may be modified on site or via remote communications.
- N. Entire system shall operate without dependency on the operator's terminal. Provide graphic generation software at each workstation.

#### 2.14 ALARMS

- A. Operator's terminal shall provide audible, visual, and printed means of alarm indication. The alarm dialog box shall always become the top dialog box regardless of the application(s), currently running (such as a word processor). Printout of alarms shall be sent to the assigned terminal and port.
- B. System shall provide log of alarm messages. Alarm log shall be archived to the hard disk of the system operator's terminal. Each entry shall include a description of the event-initiating object generating the alarm, time and date of alarm occurrence, time and date of object state return to normal, and time and date of alarm acknowledgement.
- C. Alarm messages shall be in user-definable text English (or other specified language) and shall be entered either at the operator's terminal or via remote communication.

#### 2.15 SCHEDULING

- A. Operator's terminal display of weekly schedules shall show all information in easy-to-read 7-day (weekly) format for each schedule. This includes all ON/OFF times (to the minute) for each days events.
- B. Exception schedules (non-normal schedules, such as holidays or special events) shall display all dates that are an exception to the weekly schedules. These specialty schedules shall be displayed at the operator's terminal in a format similar to the weekly schedules, again allowing easy data entry. Exception schedule data is entered by the following methods: date entries (one day entries), date-to-date (a range or span of days), and by weekday (for example, a given day of a given week each month). User shall be able to scroll easily through the months for each year as a minimum.
- C. At the operator's terminal, the system user shall be able to change all information for a given weekly or exception schedule if logged on with the appropriate security access.

#### 2.16 ARCHIVING

- A. Store back-up copies of all controllers databases in at least one OWS and/or the server(if applicable).
- B. Provide continuous supervision of integrity of all controller databases. If controller loses database, system to automatically download new copy of database to restore proper operation.

- C. Data base back up and downloading to occur over LAN without operator intervention. Operator to be able to manually download entire controller database or parts thereof.

## 2.17 REPORTS

- A. Provide a report facility to generate and format for display, printing, or permanent storage, as selected by the operator, the reports as specified in this section. If display output (CRT) is requested, it shall be scrollable; scroll bars will be used to allow easy and flexible movement within the report. Output to be sorted by area, system, point.
- B. Periodic/Automatic Report: Provide the software to automatically generate any report specified, the user will be able to specify the type of report, start time and date, interval between reports (hourly, daily, weekly, monthly) and output device. The software will allow the operator to modify the periodic/automatic reporting profile at any time.
- C. As a minimum, the following reports shall be configured on the system:
  - 1. Dynamic Reports: To allow operator to request a display of the dynamic value for the user specified points which shall indicate the status at the time the request was entered and updated at an operator modifiable scan frequency. It shall be possible to select points on the following basis:
    - a. All points in all areas
    - b. Area (all points in area)
    - c. Area system (all points in system)
    - d. Area system point (individual point)
    - e. System (all points by system and point type)
    - f. System point (all points by system and point type)
    - g. Area point (all points by area and point type).
  - 2. Summary Report: To permit the display or printing the dynamic value for the user specified points which shall indicate the status at the time the CLM was entered. Reports to be available on same basis as dynamic reports. Output will be to the user selected output device.
  - 3. Trend Reports: To permit the trending of points selected by the operator, including as a minimum digital input and output, analog input and output, set points, and calculated values.
  - 4. Historical Data Collection: Provision shall be made to ensure historical data is not lost. The ability to off-load historical data to removable media, and to later load data previously backed-up, will be provided. Historical data values, for an operator specified time range and for operator specified points, may be output the same as for trend data.
  - 5. Critical Alarm Summary: Provide a summary of those points in the critical alarm state and include as a minimum; point acronym, point description, alarm type, limit exceed, current value, alarm type, time and date of occurrence.
  - 6. Maintenance Alarm Summary: Provide a summary of those points in maintenance alarm and include as a minimum; point acronym, point description, current value, alarm type, limit exceed, time and date of occurrence.
  - 7. Alarm Summary: Provide a summary of all points in alarm and include as a minimum; point acronym, point description, current value, alarm type, limit exceeded, and time and date of occurrence.
  - 8. Disable Point Summary: Provide a summary of all points in the disabled state and include as a minimum point acronym and point description.
  - 9. Run Time Summary: Provide a summary of the accumulated running time of selected pieces of equipment with point acronym and description, run time to date, alarm limit setting. The run time shall continue to accumulate until reset individually by means of suitable operator selection.
  - 10. Schedule Summary: Provide a summary of all schedules and indicate as a minimum, which days are holidays and, for each section, the day of the week, the schedule times and

associated values; for digital schedules value will be on or off; for analog schedules value will be an analog value.

11. User Record Summary: Provide a summary of all user records to include as a minimum; user name, password, initials, command access level and point groups assigned.

## 2.18 UTILITY SOFTWARE

- A. Supply and install software products to allow the owner to access and manipulate the control schematic diagrams, and to access product data sheets in an electronic format.
- B. Enter all soft copy submissions; including "Record" drawings as specified herein [Shop Drawings, Product Data, etc.] in OWS.

## 2.19 WEB BROWSER CLIENTS

- A. The system shall be capable of supporting at least 100 simultaneous users using a standard Web browser such as Internet Explorer. Systems requiring additional software to be resident on the client machine to enable a standard Web browser, or manufacturer-specific browsers shall not be acceptable.
- B. The Web browser software shall run on any operating system and system configuration that is supported by the Web browser. Systems that require specific machine requirements in terms of processor speed, memory, etc., in order to allow the Web browser to function with the BAS, shall not be acceptable.
- C. The Web browser shall provide the same view of the system, in terms of graphics, schedules, calendars, logs, etc., and provide the same interface methodology as is provided by the Graphical User Interface. Systems that require different views or that require different means of interacting with objects such as schedules, or logs, shall not be permitted.
- D. The Web browser client shall support as a minimum, the following functions:
  1. User log-on identification and password shall be required. If an unauthorized user attempts access, a blank web page shall be displayed. Security using Java authentication and encryption techniques to prevent unauthorized access shall be implemented.
  2. Graphical screens developed for the GUI shall be the same screens used for the Web browser client. Any animated graphical objects supported by the Software shall be supported by the Web browser interface.
  3. HTML programming shall not be required to display system graphics or data on a Web page. HTML editing of the Web page shall be allowed if the user desires a specific look or format.
  4. Storage of the graphical screens shall be in the Network Control Unit (NCU), without requiring any graphics to be stored on the client machine. Systems that require graphics storage on each client are not acceptable.
  5. Real-time values displayed on a Web page shall update automatically without requiring a manual refresh of the Web page.
- E. User's shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:
  1. Modify common application objects, such as schedules, calendars, and set points in a graphical manner. Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator. Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.

- a. Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
  - b. View logs and charts
  - c. View and acknowledge alarms
  - d. Setup and execute SQL queries on log and archive information
- F. The system shall provide the capability to specify a user's home page (as determined by the log-on user identification). Provide the ability to limit a specific user to just their defined home page. From the home page, links to other views, or pages in the system shall be possible, if allowed by the system administrator.
- G. Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or on Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

### **PART 3 - EXECUTION**

#### **3.1 EXAMINATION**

- A. Verify that conditioned power supply is available to control units and operator workstation.

#### **3.2 INSTALLATION**

- A. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.
- B. Connect and configure equipment and software to achieve sequence of operation specified.
- C. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install averaging elements in ducts and plenums in crossing or zigzag pattern.
- D. Install guards on thermostats in the following locations:
  - 1. Entrances.
  - 2. Public areas.
  - 3. Where indicated.
- E. Install automatic dampers according to Division 23 Section "Air Duct Accessories."
- F. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.
- G. Install labels and nameplates to identify control components according to Division 23 Section "Identification for HVAC Piping and Equipment."
- H. Install duct volume-control dampers according to Division 23 Sections specifying air ducts.
- I. Install electronic and fiber-optic cables according to Division 27 Section "Communications Horizontal Cabling."

### 3.3 ELECTRICAL WIRING AND CONNECTION INSTALLATION

- A. Install raceways, boxes, and cabinets according to Division 26 Section "Raceway and Boxes for Electrical Systems."
- B. Install building wire and cable according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."
- C. Install signal and communication cable.
  - 1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
  - 2. Install exposed cable in raceway.
  - 3. Install concealed cable in raceway.
  - 4. Bundle and harness multiconductor instrument cable in place of single cables where several cables follow a common path.
  - 5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
  - 6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
  - 7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.
- D. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.
- E. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

### 3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.
- B. Perform the following field tests and inspections and prepare test reports:
  - 1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
  - 2. Test and adjust controls and safeties.
  - 3. Test calibration of electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
  - 4. Test each point through its full operating range to verify that safety and operating control set points are as required.
  - 5. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
  - 6. Test each system for compliance with sequence of operation.
  - 7. Test software and hardware interlocks.
- C. DDC Verification:
  - 1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
  - 2. Check instruments for proper location and accessibility.

3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
4. Check instrument tubing for proper fittings, slope, material, and support.
5. Check installation of air supply for each instrument.
6. Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.
7. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
8. Check temperature instruments and material and length of sensing elements.
9. Check control valves. Verify that they are in correct direction.
10. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.
11. Check DDC system as follows:
  - a. Verify that DDC controller power supply is from emergency power supply, if applicable.
  - b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
  - c. Verify that spare I/O capacity has been provided.
  - d. Verify that DDC controllers are protected from power supply surges.

D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

### 3.5 ADJUSTING

#### A. Calibrating and Adjusting:

1. Calibrate instruments.
2. Make three-point calibration test for both linearity and accuracy for each analog instrument.
3. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
4. Control System Inputs and Outputs:
  - a. Check analog inputs at 0, 50, and 100 percent of span.
  - b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
  - c. Check digital inputs using jumper wire.
  - d. Check digital outputs using ohmmeter to test for contact making or breaking.
  - e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.
5. Flow:
  - a. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
  - b. Manually operate flow switches to verify that they make or break contact.
6. Pressure:
  - a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
  - b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.

7. Temperature:
    - a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
    - b. Calibrate temperature switches to make or break contacts.
  8. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
  9. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
  10. Provide diagnostic and test instruments for calibration and adjustment of system.
  11. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.
- B. Adjust initial temperature and humidity set points.
- C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to three visits to Project during other than normal occupancy hours for this purpose.

### 3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls. Training shall provide at least 12 hours of training to the owner's maintenance personnel.

**END OF SECTION 23 09 00**

## SECTION 23 09 23.12 - CONTROL DAMPERS

### 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 types of control dampers and actuators for DDC systems:
  - 1. Rectangular control dampers.
  - 2. Electric and electronic actuators.
- B. Related Requirements:
  - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
  - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.12.

#### 1.3 DEFINITIONS

- A. DDC: Direct-digital control.
- B. 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 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 air and process signal tubing.
5. Include diagrams for pneumatic signal and main air tubing.

C. Delegated-Design Submittal:

1. Schedule and design calculations for control dampers and actuators, including the following.
  - 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 500D 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.

1.5 INFORMATIONAL SUBMITTALS

- 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. Product installation location shown in relationship to room, duct, and equipment.
  2. Size and location of wall access panels for control dampers and actuators installed behind walls.
  3. Size and location of ceiling access panels for control dampers and actuators installed above inaccessible ceilings.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For control dampers to include in operation and maintenance manuals.

**PART 2 - PRODUCTS**

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.
- 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. Environmental Conditions:
  - 1. Provide electric control-damper actuators, with protective enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Electric control-damper actuators not available with integral enclosures, complying with requirements indicated, shall be housed in protective secondary enclosures.
- F. Selection Criteria:
  - 1. Control dampers shall be suitable for operation at following conditions:
    - A. Leakage:
      - i. Dampers shall have a maximum leakage of Class 1 @ 4 in. wg as defined by AMCA (Leakage class 1 is defined as 8 cfm/ sq. ft. @ 4 in. wg). Tested in accordance with AMCA standard 500-D.
      - ii. Damper shall meet or exceed the IECC (International Energy Conservation Code) requirements for damper leakage ratings of 3 cfm per sq. ft. @ 1 in. wg or 8 cfm per sq. ft @ 4 in. wg or less when integral to the building envelope.
    - B. Differential Pressure:
      - i. Dampers shall have a maximum differential pressure rating of 8 in. wg.
    - C. Velocity:
      - ii. Dampers shall have a maximum velocity rating of 4000 fpm (20.32 m/s).
  - 2. Fail positions unless otherwise indicated:
    - a. Supply Air: **Last position.**
    - b. Return Air: **Open.**
    - c. Outdoor Air: **Close.**
    - d. Mixed Air: **Last position.**
    - e. Exhaust Air: **Last position.**
  - 3. Dampers shall have stable operation throughout full range of operation, from design to minimum airflow over varying pressures and temperatures encountered.
  - 4. Select modulating dampers for a pressure drop of 5 percent of fan total static pressure unless otherwise indicated.
  - 5. Two-position dampers shall be full size of duct or equipment connection unless otherwise indicated.
  - 6. Control-damper, provide an electric/electronic control signal to the damper and an electric valve at the damper.

## 2.2 RECTANGULAR CONTROL DAMPERS

- A. General Requirements:
  - 1. Unless otherwise indicated, use parallel blade configuration for two-position control, 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 the 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 Airfoil Blades:

1. Construction:

a. Frame:

- 1) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, **0.07 inch** thick or heavier.
- 2) Hat-shaped channel with integral flange(s). 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 B 211, 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) Jamb: Stainless steel, compression type.

d. Axles: **0.5-inch** diameter **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, provide thrust bearings.

f. Linkage:

- 1) Concealed in frame.
- 2) Constructed of aluminum and **or stainless** steel.
- 3) Hardware: Stainless steel.

g. Transition:

- 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
- 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
- 3) Damper size and sleeve shall be connection size plus **2 inches**.
- 4) Sleeve length shall be not less than **12 inches** for dampers without jackshafts and shall be not less than **16 inches** for dampers with jackshafts.
- 5) Sleeve material shall match adjacent duct.

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.
2. Airflow Measurement:
- a. Where indicated on drawings, provide damper assembly with integral airflow monitoring.
  - b. Zero to 10V dc or 4 to 20mA scaled output signal for remote monitoring of actual airflow.
  - c. Accuracy shall be within 5 percent of the 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 the damper sections and flow measurement assembly as required to comply with the stated accuracy over the entire modulating range.
  - d. Provide a straightening device as part of the flow measurement assembly to achieve the specified accuracy with configuration indicated.
  - e. Suitable for operation in untreated and unfiltered air.
  - f. Provide temperature and altitude compensation and correction to maintain accuracy over temperature range encountered at site altitude.
  - g. Provide automatic zeroing feature.
3. Airflow Control:
- a. Where indicated, provide damper assembly with integral airflow measurement and control.
  - b. A factory-furnished and -calibrated controller shall be programmed, in nonvolatile EPROM, with application-specific airflow set point and range.
  - c. The controller and actuator shall communicate to control the desired airflow.
  - d. The controller shall receive a zero to 10V dc input signal and report a zero to 20mA output signal that is proportional to the airflow.
  - e. Airflow measurement and control range shall be suitable for operation between **150 to 2000 fpm**.
  - f. Ambient Operating Temperature Range: **0 to plus 140 deg F**.
  - g. Ambient Operating Humidity Range: 5 to 95 percent relative humidity, non-condensing.
  - h. Provide unit with control transformer rated for not less than 85 VA. Provide transformer with primary and secondary protection and primary disconnecting means. Coordinate requirements with field power connection.
  - i. Provide screw terminals for interface to field wiring.
  - j. Factory mount electronics within a NEMA 250, Type 1 painted steel enclosure.

### 2.3 GENERAL CONTROL-DAMPER ACTUATORS REQUIREMENTS

- 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 the 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. The total damper area operated by an actuator shall not exceed 80 percent of manufacturer's maximum area rating.

- D. Provide one actuator for each damper assembly where possible. Multiple actuators required to drive a single damper assembly shall operate in unison.
- E. Avoid the 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. Provide mounting hardware and linkages for connecting actuator to damper.
- H. Select actuators to fail in desired position in the event of a power failure.

## 2.4 ELECTRIC AND ELECTRONIC ACTUATORS

- A. Type: Motor operated, with or without gears, electric and electronic.
- B. Voltage:
  - 1. **Voltage selection is delegated to professional designing control system.**
  - 2. Actuator shall deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
  - 3. Actuator shall function properly within a range of 85 to 120 percent of nameplate voltage.
- C. Construction:
  - 1. Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
  - 2. 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.
  - 3. Greater Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.
- D. Field Adjustment:
  - 1. Spring return actuators shall be easily switchable from fail open to fail closed in the field without replacement.
  - 2. Provide gear-type actuators with an external manual adjustment mechanism to allow manual positioning of the damper when the actuator is not powered.
- E. Two-Position Actuators: Single direction, spring return or reversing type (In Duct).
- F. Modulating Actuators (under stage):
  - 1. Capable of stopping at all points across full range and starting in either direction from any point in range.
  - 2. Control Input Signal:
    - a. Three Point, Tristate, or Floating Point: Clockwise and counterclockwise 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 0 to **10Vdc** or **4 to 20mA** signals.

- c. Pulse Width Modulation (PWM): Actuator drives to a specified position according to a pulse duration (length) of signal from a dry-contact closure, triac sink or source controller.
- d. Programmable Multi-Function:
  - 1) Control input, position feedback, and running time shall be factory or field programmable.
  - 2) Diagnostic feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
  - 3) Service data, including at a minimum, number of hours powered and number of hours in motion.

G. Position Feedback:

- 1. **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. **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.

H. 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.

I. 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.

J. Damper Attachment:

- 1. Unless otherwise required for damper interface, provide actuator designed to be directly coupled to damper shaft without need for connecting linkages.
- 2. Attach actuator to damper 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.

K. Temperature and Humidity:

- 1. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of **0 to plus 120 deg F**.
- 2. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from **5 to 98** percent relative humidity, non-condensing.

L. 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 a heater and controller where required by application.

M. Stroke Time:

1. Operate damper from fully closed to fully open within **15** seconds.
2. Operate damper from fully open to fully closed within 15 seconds.
3. Move damper to failed position within **5** seconds.
4. Select operating speed to be compatible with equipment and system operation.
5. Actuators operating in smoke control systems comply with governing code and NFPA requirements.

N. Sound:

1. Spring Return: 62 dBA.
2. Non-Spring Return: 45 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 dampers and instruments installed in duct systems to verify actual locations of 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-DAMPER APPLICATIONS

- A. Control Dampers: See drawings.

#### 3.3 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy most stringent requirements indicated.
- B. Properly support dampers and actuators, tubing, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway
- C. 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.
- D. Seal penetrations made in fire-rated and acoustically rated assemblies.
- E. Fastening Hardware:

1. Stillson wrenches, pliers, or 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.
- F. 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.
- G. Coastal (within 60 miles) and/or 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.
    - c. Coastal intake
    - d. Coastal exhaust
  3. Use Type 316L stainless-steel tubing and fittings when in contact with a corrosive environment.
  4. When conduit is in contact with a corrosive environment, use Type 316L stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
  5. Where actuators 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 DAMPERS

- A. Install smooth transitions, not exceeding **30** degrees, to dampers smaller than adjacent duct. Install transitions as close to damper as possible but at distance to avoid interference and impact to performance. Consult manufacturer for recommended clearance.
- B. Clearance:
  1. Locate dampers for easy access and provide separate support of dampers that cannot be handled by service personnel without hoisting mechanism.

2. Install dampers with at least **24 inches** of clear space on sides of dampers requiring service access.

C. Service Access:

1. Dampers and actuators shall be accessible for visual inspection and service.
2. Install access door(s) in duct or equipment located upstream of damper to allow service personnel to hand clean any portion of damper, linkage, and actuator. Comply with requirements in Section 233300 "Air Duct Accessories."

- D. Install dampers straight and true, level in all planes, and square in all dimensions. Install supplementary structural steel reinforcement for large multiple-section dampers if factory support alone cannot handle loading.

- E. Attach actuator(s) to damper drive shaft.

- F. For duct-mounted and equipment-mounted dampers installed outside of equipment, install a visible and accessible indication of damper position from outside.

- G. Coordinate with other trades for wiring that must pass around damper under the stage.

### 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 damper identification on damper **and on face of ceiling where damper is concealed above ceiling.**

### 3.8 CHECKOUT PROCEDURES

A. Control-Damper Checkout:

1. Check installed products before continuity tests, leak tests, and calibration.
2. Check dampers for proper location and accessibility.
3. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.
4. For pneumatic products, verify air supply for each product is properly installed.
5. For pneumatic dampers, verify that pressure gages are provided in each air line to damper actuator and positioner.
6. Verify that control dampers are installed correctly for flow direction.
7. Verify that proper blade alignment, either parallel or opposed, has been provided.
8. Verify that damper frame attachment is properly secured and sealed.
9. Verify that damper actuator and linkage attachment are secure.
10. Verify that actuator wiring is complete, enclosed, and connected to correct power source.

11. Verify that damper blade travel is unobstructed.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING:

- A. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed back to 100 percent open.
- B. 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.
- C. Check and document open and close cycle times for applications with a cycle time of less than 30 seconds.
- D. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

**END OF SECTION 23 09 23.12**

## SECTION 23 23 00 - REFRIGERANT PIPING

### 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. 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.
- B. Sustainable Design Submittals:
  - 1. No CFC or HCFC refrigerants shall be used.
  - 2. Any existing equipment refrigerant shall be recovered and returned to Owner.
- C. Shop Drawings:
  - 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**.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.
- B. Refrigerant Logs for project.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For refrigerant valves and piping specialties to include in maintenance manuals.

1.6 QUALITY ASSURANCE

- A. Comply with ASHRAE 15, "Safety Code for Refrigeration Systems."
- B. 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**

2.1 COPPER TUBE AND FITTINGS

- A. Copper Tube: **ASTM B 88, Type K or L and ASTM B 280, Type ACR.**
- B. Wrought-Copper Fittings: ASME B16.22.
- C. Wrought-Copper Unions: ASME B16.22.
- D. Brazing Filler Metals: AWS A5.8/A5.8M.
- E. 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.**

2.2 STEEL PIPE AND FITTINGS (Large refrigerant lines)

- 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 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**.

## 2.3 VALVES AND SPECIALTIES

- A. Check Valves:
  - 1. Body: Ductile iron, forged brass, or cast bronze; globe pattern depending on piping and dielectric conditions.
  - 2. Bonnet: Bolted ductile iron, forged brass, or cast bronze; or brass hex plug.
  - 3. Piston: Removable polytetrafluoroethylene seat.
  - 4. Closing Spring: Stainless steel.
  - 5. Manual Opening Stem: Seal cap, plated-steel stem, and graphite seal.
  - 6. End Connections: Socket, union, threaded, or flanged.
  - 7. Maximum Opening Pressure: **0.50 psig**.
  - 8. Working Pressure Rating: **500 psig**
  - 9. Maximum Operating Temperature: **275 deg F** .
- B. Service Valves:
  - 1. Body: Forged brass with brass cap including key end to remove core.
  - 2. Core: Removable ball-type check valve with stainless-steel spring.
  - 3. Seat: Polytetrafluoroethylene.
  - 4. End Connections: Copper spring.
  - 5. Working Pressure Rating: **500 psig**.

- C. Solenoid Valves: Comply with AHRI 760 and UL 429; listed and labeled by a National Recognized Testing Laboratory (NRTL).
  - 1. Body and Bonnet: Plated steel.
  - 2. Solenoid Tube, Plunger, Closing Spring, and Seat Orifice: Stainless steel.
  - 3. Seat: Polytetrafluoroethylene.
  - 4. End Connections: Threaded or brazed. .
  - 5. Electrical: Molded, watertight coil in NEMA 250 enclosure of type required by location with **1/2-inch** conduit adapter, and **24, 115 or 208V** ac coil.
  - 6. Working Pressure Rating: **400 psig**.
  - 7. Maximum Operating Temperature: **240 deg F**.
  
- D. Thermostatic Expansion Valves: Comply with AHRI 750.
  - 1. Per coil manufacturers specification on performance
  
- E. Permanent Filter Dryers: Comply with AHRI 730.
  - 1. Body and Cover: Painted-steel shell.
  - 2. Filter Media: 10 micron, pleated with integral end rings; stainless-steel support.
  - 3. Desiccant Media: Rated for Hot Gas Discharge line, Solid Core.
  - 4. Designed for reverse flow.
  - 5. End Connections: Socket.
  - 6. Access Ports: **NPS 1/4** connections at entering and leaving sides for pressure differential measurement.
  - 7. Maximum Pressure Loss: **2 psig**.
  - 8. Working Pressure Rating: **500 psig**.
  - 9. Maximum Operating Temperature: **240 deg F**.

### PART 3 - EXECUTION

#### 3.1 VALVE AND SPECIALTY APPLICATIONS

- A. 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.
  
- B. Install a check valve at the compressor discharge and a liquid accumulator at the compressor suction connection.
  
- C. Install solenoid valves at discharge of condenser in liquid line when evaporator is above condenser and refrigerant lines exceed 25'.
  
- D. 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.
  
- E. Install moisture/liquid indicators in liquid line at the inlet of the thermostatic expansion valve or at the inlet of the fixed metering device.
  
- F. Install filter dryers in liquid line between compressor and thermostatic expansion valve, **and in the suction line at the compressor**.
  
- G. Install receivers sized to accommodate pump-down charge.
  
- H. Install flexible connectors at outdoor unit line set connections.

### 3.2 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:
  - 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.
  - 3. Install traps and double risers to entrain oil in vertical runs.
  - 4. Liquid lines may be installed level.
- P. When brazing, 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.

- 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, lint-less cloth through tubing by means of a wire or electrician's tape.
  3. Draw a clean, lint-less cloth saturated with trichloroethylene through the tube or pipe. Continue this procedure until cloth is not discolored by dirt.
  4. Draw a clean, lint-less 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, lint-less 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."
- 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."
- W. Insulated refrigerant piping in accordance with applicable Energy Code referenced on drawings.

### 3.3 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. Fill pipe and fittings with an inert gas (nitrogen or carbon dioxide), during brazing or welding, to prevent scale formation.
- D. 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.
- E. 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.

F. Steel pipe can be threaded, but threaded joints must be seal brazed or seal welded.

G. Welded Joints: Construct joints according to AWS D10.12M/D10.12.

H. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

### 3.4 HANGERS AND SUPPORTS

A. Comply with requirements for pipe hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. 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.

C. Support multi-floor vertical runs at least at each floor.

### 3.5 FIELD QUALITY CONTROL

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.

B. Prepare test and inspection reports.

### 3.6 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.

### 3.7 ADJUSTING

- 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 23 23 00**

## SECTION 23 29 23 - VARIABLE-FREQUENCY MOTOR CONTROLLERS

### PART 1 - GENERAL

#### 1.1 SUMMARY

- A. This Section includes solid-state, PWM, VFCs for speed control of three-phase, squirrel-cage induction motors.
- B. Related Sections include the following:
  - 1. Division 26 Section "Electrical Power Monitoring and Control" for monitoring and control of motor circuits.
  - 2. Division 26 Section "Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits" for low-voltage power, control, and communication surge suppressors.

#### 1.2 DEFINITIONS

- A. BMS: Building management system.
- B. IGBT: Integrated gate bipolar transistor.
- C. LAN: Local area network.
- D. PID: Control action, proportional plus integral plus derivative.
- E. PWM: Pulse-width modulated.
- F. VFC: Variable frequency controller.

#### 1.3 SUBMITTALS

- A. Product Data: For each type of VFC. Include product brochure with dimensions, mounting arrangements, location for conduit entries, wiring diagrams for drive and bypass contactor, shipping and operating weights, and manufacturer's technical data on features, performance, electrical ratings, characteristics, and finishes. List optional features available.
- B. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFCs where pipe and ducts are prohibited. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.
- C. Operation and Maintenance Data: For VFCs, all installed devices, and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:
  - 1. Routine maintenance requirements for VFCs and all installed components.

2. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.

#### 1.4 QUALITY ASSURANCE

- A. Manufacturer Qualifications: A qualified manufacturer. Maintain, within 100 miles of Project site, a service center capable of providing training, parts, and emergency maintenance and repairs.
- B. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.
  1. Testing Agency's Field Supervisor: Person currently certified by the InterNational Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.
- C. Source Limitations: Obtain VFCs of a single type through one source from a single manufacturer.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- E. Comply with NFPA 70.
- F. Harmonics
  1. All devices shall comply with IEEE 519 - 2022.
  2. Voltage Distortion
    - a. Individual devices shall have voltage distortion limits per IEEE 519-2022 Table 1 and individual harmonics shall **not exceed 3%**.
    - b. Total Harmonic Distortion (THD) for the sum of all devices shall not exceed the values of 5% or IEEE 519:2022 table 1 whichever is less.
  3. Current Distortion
    - a. All devices shall comply with the current distortion limits of IEEE 519:2022, Table 2.
    - b. Line notching shall not exceed 16,400 volt-microseconds.
    - c. Line reactors, chokes or reduced harmonic technology shall be utilized to meet IEEE 519:2022.
- G. Designed to limit RFI/EMI interference in accordance with FCC Regulation Part 15, subpart J for Class A computing devices or IEC61800-3 categories C1, C2 and C3
- H. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFCs, minimum clearances between VFCs, and adjacent surfaces and other items. Comply with indicated maximum dimensions and clearances.

#### 1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver VFCs in shipping splits of lengths that can be moved past obstructions in delivery path as indicated.
- B. Store VFCs indoors in clean, dry space with uniform temperature to prevent condensation. Protect VFCs from exposure to dirt, fumes, water, corrosive substances, and physical damage.
- C. If stored in areas subject to weather, cover VFCs to protect them from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside controllers; install electric heating of sufficient wattage to prevent condensation.

#### 1.6 PROJECT CONDITIONS

- A. Environmental Limitations: Rate equipment for continuous operation, capable of driving full load without derating, under the following conditions, unless otherwise indicated:
  - 1. Drive Operating Ambient Temperature: 32 to 104 deg F.
  - 2. Drive Storage Ambient Temperature: 68 to 104 deg F.
  - 3. Humidity: Less than 90 percent (noncondensing).
  - 4. Altitude: Not exceeding 3300 feet.
- B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFCs, including clearances between VFCs, and adjacent surfaces and other items. Comply with indicated maximum dimensions.

#### 1.7 COORDINATION

- A. Coordinate layout and installation of VFCs 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 size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."
- C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."
- D. Coordinate features of VFCs, installed units, and accessory devices with pilot devices and control circuits to which they connect.
- E. Coordinate features, accessories, and functions of each VFC and each installed unit with ratings and characteristics of supply circuit, motor, required control sequence, and duty cycle of motor and load.

#### 1.8 EXTRA MATERIALS

- A. Furnish manufacturers recommended spare parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
  - 1. Spare Fuses: Furnish one spare for every five installed, but no less than one set of three of each type and rating.
  - 2. Indicating Lights: Two of each type installed.

3. Extra control pad: Two of each type installed

## 1.9 WARRANTY

- A. Manufacturer's warranty: Labor and materials for a period of one year from date of start-up, not to exceed 18 months from date of shipment.
- B. During the warranty period, any warranty expense shall be born by the manufacturer, including travel costs or living expenses necessary to repair in-warranty equipment.

## PART 2 - PRODUCTS

### 2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  1. Schneider Electric, Square D
  2. ABB Power Distribution, Inc.; ABB Control, Inc. Subsidiary.
  3. Eaton Corporation; Cutler-Hammer Products.
  4. Emerson.
  5. Toshiba

### 2.2 VARIABLE FREQUENCY CONTROLLERS

- A. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.
  1. Provide unit suitable for operation of premium-efficiency motor as defined by NEMA MG 1. VFD rated motors per Nema MG 1 part 31 are preferred.
  2. Solid state design to transform input power into frequency and voltage controlled 3-phase output power suitable to provide positive speed and torque control to standard induction motors.
  3. Front end: Provide with input line filters as an integral part of drive.
  4. Inverter section: Transistorized sinecode pulse width modulation. Employ power transistors in the inverter without paralleling.
  5. An increase in audible motor noise (with drive operating) shall not exceed 3 decibels.
  6. Power factor: Minimum of 0.95 and an efficiency of 98% at 100% full output.
  7. Low voltage and Medium-voltage drives shall be provided with an output filter and/or a dv/dt filter if VFD rated motors per Nema MG 1 Part 31 motors are not utilized.
  8. Medium-voltage drives shall be provided with insulated motor bearings and a shaft grounding brush arrangement if VFD rated motors per Nema MG 1 Part 31 are not utilized.
  9. .
- B. Design and Rating: Match load type such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.
  1. Provide symmetrical A/C rating of 100,000 amps for fused input devices.

2. Provide symmetrical A/C ratings of 100,000 amps for other than fused input drives at 460 volts and 35,000 amps for other than fused inputs at lower voltages.
  3. Provide higher ratings where available fault current exceeds these levels and as called for on the drawings.
- C. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.
- D. Unit Operating Requirements:
1. Input ac voltage tolerance of 380 to 500 V, plus or minus 10 percent. 60 HZ +/- 3%.
  2. Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
  3. Horsepower Rating: As scheduled on the Drawings.
  4. Output power: 0-460 volts, 1-60 Hz.
  5. Output frequency stability shall not vary with load, temperature, or with +/- 10% input frequency variations.
  6. Minimum Efficiency: 98 percent at 60 Hz, full load.
  7. Minimum Displacement Primary-Side Power Factor: 99 percent.
  8. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
  9. Starting Torque: 100 percent of rated torque or as indicated.
  10. Speed Regulation: Plus or minus 1 percent.
- E. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
1. Electrical Signal: 4 to 20 mA at 24 V.
- F. Internal Adjustability Capabilities:
1. Minimum Speed: 5 to 25 percent of maximum rpm.
  2. Maximum Speed: 80 to 100 percent of maximum rpm.
  3. Acceleration: 2 to a minimum of 22 seconds.
  4. Deceleration: 2 to a minimum of 22 seconds.
  5. Current Limit: 50 to a minimum of 110 percent of maximum rating.
- G. Self-Protection and Reliability Features:
1. Input transient protection by means of surge suppressors.
  2. Under- and overvoltage trips; inverter overtemperature, overload, and overcurrent trips to protect the inverter due to voltage levels in excess of its rating. Activates automatically when the DC bus in the controller exceeds 1000 VDC. Overtemperature trip shall protect the inverter from elevated temperatures in excess of rated temperatures.
  3. Drive Logic shall be microprocessor-based.
  4. Motor Overload Relay: Adjustable and capable of NEMA ICS 2, Class 10 or 20 or 30 performance.
  5. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
  6. Instantaneous line-to-line and line-to-ground overcurrent trips: To limit the output current in under 50 microseconds due to phase-to-phase short circuits or severe overload conditions.
  7. Loss-of-phase protection.
  8. Momentary power loss: the VFC shall shut down without component failure. Upon return of power, automatically return the drive to normal operation, if the start is in the "ON" condition, being able to restart into a rotating motor regaining positive speed control without shutdown or component failure.

9. Sustained power loss: the VFC shall shut down without component failure. Upon return of power, automatically return drive to normal operation if the start is in the "ON" condition.
  10. Power interruption: In the event that an input or output power contactor is opened or closed while the drive is activated, no damage to the control shall result.
  11. Critical frequency avoidance circuit: provide a minimum of six user-selectable bands to avoid operation at speeds which cause excessive vibration or noise in the driven equipment.
  12. Reverse-phase protection.
  13. Short-circuit protection: in the event of a phase-to-phase short circuit, VFC shall shutdown safely without component failure.
  14. Isolation: isolated current and voltage signals from logic circuitry.
  15. Motor overtemperature fault.
  16. Current Limit: To limit the output current to 110% of inverter rating.
  17. Automatic Reset/Restart:
    - a. Provide automatic reset on trip condition resulting from overcurrent, overvoltage, undervoltage, or overtemperature after removal or correction of the causative condition.
    - b. Provide an unlimited number of reset/restarts for overvoltage, undervoltage, and overtemperature.
    - c. Limit the number of reset/restarts for overcurrent and require manual reset.
- H. Multiple-Motor Capability: Controller suitable for service to multiple motors and having a separate overload relay and protection for each controlled motor. Overload relay shall shut off controller and motors served by it when overload relay is tripped.
- I. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional autospeed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.
- J. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped.
- K. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
- L. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
- M. Status Lights: Door-mounted LED indicators shall indicate the following conditions:
1. Power on.
  2. Zero Speed.
  3. Run.
  4. Over Voltage.
  5. Line fault.
  6. Over Current.
  7. Over Temperature.
  8. Under Voltage.
  9. % Speed.
  10. % Load.
  11. External fault.

- N. Panel-Mounted Operator Station: Start-stop and auto-manual selector switches with manual speed control potentiometer and elapsed time meter.
  
- O. Indicating Devices: Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:
  - 1. Output frequency (Hz).
  - 2. Motor speed (rpm).
  - 3. Motor status (running, stop, fault).
  - 4. Motor current (amperes).
  - 5. Motor torque (percent).
  - 6. Fault or alarming status (code).
  - 7. PID feedback signal (percent).
  - 8. DC-link voltage (VDC).
  - 9. Set-point frequency (Hz).
  - 10. Motor output voltage (V).
  
- P. Control Signal Interface:
  - 1. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
  - 2. Remote Signal Inputs: Capability to accept any of the following adjustable speed-setting input signals from the BMS or other control systems:
    - a. 0 to 10-V dc.
    - b. 0-20 or 4-20 mA.
    - c. Potentiometer using up/down digital inputs, 5000 OHM.
    - d. Fixed frequencies using digital inputs.
    - e. RS485.
    - f. Keypad display for local hand operation.
  - 3. Output Signal Interface:
    - a. A minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:
      - 1) Output frequency (Hz).
      - 2) Output current (load).
      - 3) DC-link voltage (VDC).
      - 4) Motor torque (percent).
      - 5) Motor speed (rpm).
      - 6) Set-point frequency (Hz).
  - 4. Remote Indication Interface: A minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
    - a. Motor running.
    - b. Set-point speed reached.
    - c. Fault and warning indication (overtemperature or overcurrent).
    - d. PID high- or low-speed limits reached.
  - 5. Start-Stop Control: VFC drive may be started or stopped by any one of the following:
    - a. Contact Closure.
    - b. The use of a motor starter or contactor in the input power line.

- c. An external 115 VAC signal.
  - d. The speed control signal dropping below or rising above the minimum.
- Q. Communications: Provide an RS485 interface allowing VFC to be used with an external Facility Management System (FMS). Provide VFC with BACnet interface to duplicate all points monitored locally at VFC into the FMS. Interface shall connect to FMS network communication bus. Interface shall also allow all parameter settings of VFC to be programmed via FMS control. Provide capability for VFC to retain these settings within the nonvolatile memory.
- R. Bypass: Provide an integral bypass contactor for operation of motor at constant speed, electrically independent of the inverter. Include motor overload protection when in bypass mode. Include all necessary switches and control relays to allow automatic controls and safeties to operate when drive is in bypass mode.
- S. Integral Disconnecting Means: NEMA AB 1, instantaneous-trip (magnetic) circuit breaker or NEMA KS 1, non-fusible switch with lockable handle.

## 2.3 ENCLOSURES

- A. NEMA 1 enclosure with dead-sides for installation in an individual wall installation, inside a building.
- B. NEMA 4 or 4X enclosure for devices mounted outdoors.

## 2.4 ACCESSORIES

- A. Devices shall be factory installed in controller enclosure, unless otherwise indicated.
- B. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
- C. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.
- D. Control Relays: Auxiliary and adjustable time-delay relays.
- E. Standard Displays:
  - 1. Output frequency (Hz).
  - 2. Set-point frequency (Hz).
  - 3. Motor current (amperes).
  - 4. DC-link voltage (VDC).
  - 5. Motor torque (percent).
  - 6. Motor speed (rpm).
  - 7. Motor output voltage (V).
- F. Historical Logging Information and Displays:
  - 1. Real-time clock with current time and date.
  - 2. Running log of total power versus time.
  - 3. Total run time.
  - 4. Fault log, maintaining last four faults with time and date stamp for each.

- G. Current-Sensing, Phase-Failure Relays for Bypass Controller: Solid-state sensing circuit with isolated output contacts for hard-wired connection; arranged to operate on phase failure, phase reversal, current unbalance of from 30 to 40 percent, or loss of supply voltage; with adjustable response delay.
- H. 115 Volt AC Power Supply used to provide a remote-enabled indication.
- I. Customer Contacts: Provide a single pole, double throw contact which changes state on trip condition.

## 2.5 FACTORY FINISHES

- A. Finish: Manufacturer's standard paint applied to factory-assembled and -tested VFCs before shipping.

## PART 3 - EXECUTION

### 3.1 EXAMINATION

- A. Examine areas, surfaces, and substrates to receive VFCs for compliance with requirements, installation tolerances, and other conditions affecting performance.
- B. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

### 3.2 APPLICATIONS

- A. Select features of each VFC to coordinate with ratings and characteristics of supply circuit and motor; required control sequence; and duty cycle of motor, controller, and load.
- B. Select horsepower rating of controllers to suit motor controlled.

### 3.3 INSTALLATION

- A. Anchor each VFC assembly to steel-channel sills arranged and sized according to manufacturer's written instructions. Attach by bolting. Level and grout sills flush with mounting surface.
- B. Install VFCs on concrete bases.
- C. VFC's within twenty-five (25) feet of motor being controlled shall have an integral non-fused disconnect on the line side of the VFC. Reference requirements in Division 26 Section 26 28 16 "Enclosed Switches and Circuit Breakers" for switches.
- D. Comply with mounting and anchoring requirements specified in Division 26 Section "Hangers and Supports for Electrical Systems."

- E. Controller Fuses: Install fuses in each fusible switch. Comply with requirements in Division 26 Section "Fuses."
- F. Coordinate installation with requirements for HVAC temperature controls.

### 3.4 CONCRETE BASES (For those VFC's where they need to be floor mounted)

- A. Coordinate size and location of concrete bases. Verify structural requirements with structural engineer.
- B. Concrete base is specified in Division 26 Section "Common Work Results for Electrical," and concrete materials and installation requirements are specified in Division 03.

### 3.5 IDENTIFICATION

- A. Identify VFCs, components, and control wiring according to Division 26 Section "Identification for Electrical Systems." Nameplates shall be attached with screws or rivets (adhesives shall not be used to secure nameplates).
- B. Label VFC's with an indication as to which AHU or motor they serve.
- C. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

### 3.6 CONTROL WIRING INSTALLATION

- A. Install wiring between VFCs and remote devices according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."
- B. Control systems, components, and control and interlock wiring for mechanical equipment will be furnished under this Division.
- C. Bundle, train, and support wiring in enclosures.
- D. Connect hand-off-automatic switch and other automatic-control devices where applicable.
  - 1. Connect selector switches to bypass only manual- and automatic-control devices that have no safety functions when switch is in hand position.
  - 2. Connect selector switches with control circuit in both hand and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

### 3.7 CONNECTIONS

- A. Conduit installation requirements are specified in other Division 26 Sections. Drawings indicate general arrangement of conduit, fittings, and specialties.
- B. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

- C. Fire Alarm control wiring among duct-mounted smoke detectors, fire alarm system, ATC Panels, drives, or DDC panels shall be furnished under Division 26.
- D. Provide power wiring to drives under Division 26. Power wiring shall consist of wiring to the line side terminals wiring away from the load side terminals to the equipment, except where such wiring is installed pre-wired by the equipment vendor such as for chiller units.

### 3.8 FIELD QUALITY CONTROL

- A. Prepare for acceptance tests as follows:
  - 1. Test insulation resistance for each enclosed controller element, bus, component, connecting supply, feeder, and control circuit.
  - 2. Test continuity of each circuit.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to perform the following:
  - 1. Inspect controllers, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
  - 2. Assist in field testing of equipment including pretesting and adjusting of solid-state controllers.
  - 3. Report results in writing.
- C. Testing Agency: Engage a qualified testing and inspecting agency to perform the following field tests and inspections and prepare test reports:
- D. Perform the following field tests and inspections and prepare test reports:
  - 1. Perform each electrical test and visual and mechanical inspection, except optional tests, stated in NETA ATS. 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.

### 3.9 ADJUSTING

- A. Set field-adjustable switches and circuit-breaker trip ranges.
- B. Provide the necessary coordination for Test and Balance Procedures as required by this Division.

### 3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain variable frequency controllers. Refer to Division 01 Section "Demonstration and Training."

**END OF SECTION 23 29 23**

## SECTION 23 31 13 - METAL DUCTS

### PART 1 - GENERAL

#### 1.1 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Sheet metal materials.
3. Duct liner.
4. Sealants and gaskets.
5. Hangers and supports.

B. Related Sections:

1. Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Division 23 Section "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.
3. Division 23 Section "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.
4. References to SMACNA's Duct manuals shall be in reference to the most current version.

#### 1.2 PERFORMANCE REQUIREMENTS

- A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with the most current version of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article. Duct shall be 20 gauge or thicker to prevent noise. Consider this duct to be exterior as it is when the stage front is open.
- B. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible". Including the nature of how the anchors are secured to the structure.
- C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1 most current version and LEED requirements for most current version. Materials shall also dampen sound transmission.
- D. Paint: Duct exterior shall be painted flat black where it is exposed in the performance area around the stage.

#### 1.3 SUBMITTALS

- A. Product Data: For each type of the following products:
1. Liners and adhesives.

2. Sealants and gaskets.

B. 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 of ducts.
5. Dimensions of main 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 and vibration isolation.

C. 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.

D. Coordination Drawings: 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. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
2. Suspended ceiling components.
3. Structural members to which duct will be attached.
4. Size and location of initial access modules for acoustical tile.
5. Penetrations of smoke barriers and fire-rated construction.
6. Items penetrating finished ceiling including the following:
  - a. Lighting fixtures.
  - b. Air outlets and inlets.
  - c. Speakers.
  - d. Sprinklers.
  - e. Access panels.
  - f. Perimeter moldings.

E. Field quality-control reports and TAB reports.

#### 1.4 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

- B. Welding Qualifications: Qualify procedures and personnel according to 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 D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.
- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."
- D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

## **PART 2 - PRODUCTS**

### **2.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS**

- A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
- B. Transverse Joints: Select joint types and fabricate according to 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."
- C. Longitudinal Seams: Select seam types and fabricate according to 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."
- D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 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."

### **2.2 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.
- B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
  - 1. Galvanized Coating Designation: G90.
  - 2. Finishes for Surfaces Exposed to View: Mill phosphatized.

- C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.
- D. Aluminum Sheets: Comply with ASTM B 209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.
- E. Reinforcement Shapes and Plates: ASTM A 36/A 36M, 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.
- 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 DUCT LINER

- A. Fibrous-Glass Duct Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
  - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    - a. CertainTeed Corporation; Insulation Group.
    - b. Johns Manville.
    - c. Knauf Insulation.
    - d. Owens Corning.
    - e. Maximum Thermal Conductivity:
      - 1) Type I, Flexible: 0.27 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
      - 2) Type II, Rigid: 0.23 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
  - 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. Water-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.
    - a. For this application, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- B. 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-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; with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

- C. 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.
  6. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpm.
  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.
  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.

## 2.4 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 according to UL 723; certified by an NRTL.
- 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: 4 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.
10. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

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.

## 2.5 HANGERS AND SUPPORTS

- A. Hanger Rods for Noncorrosive Environments: Cadmium-plated 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 A 603.
- E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.
- F. Steel Cable End Connections: Cadmium-plated 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.
- I. Painting: All materials visible in the stage and stage support areas must be painted flat black.

## PART 3 - EXECUTION

### 3.1 DUCT INSTALLATION

- 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 according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
- C. Install round and flat-oval ducts in maximum practical lengths.
- D. Install ducts with fewest possible joints.
- E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.
- F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
- G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
- 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. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."

### 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 the 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 DUCT SEALING

- A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

- B. Seal ducts to the following seal classes according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" definition of Sealing.:
  - 1. Outdoor, Supply-Air Ducts: Seal Class A.
  - 2. Outdoor, Exhaust Ducts: Seal Class A.
  - 3. Outdoor, Return-Air Ducts: Seal Class A.
  - 4. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class A.
  - 5. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
  - 6. Unconditioned Space, Exhaust Ducts: Seal Class A.
  - 7. Unconditioned Space, Return-Air Ducts: Seal Class A.
  - 8. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class A.
  - 9. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
  - 10. Conditioned Space, Exhaust Ducts: Seal Class A
  - 11. Conditioned Space, Return-Air Ducts: Seal Class A.

### 3.4 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."
- 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.
- 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. Painted flat black.
- 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.

### 3.5 CONNECTIONS

- A. Make connections to equipment with flexible connectors complying with Division 23 Section "Air Duct Accessories."

- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

### 3.6 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.

### 3.7 FIELD QUALITY CONTROL

- A. Perform tests and inspections.

- B. Leakage Tests:

1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test to the Engineer.
2. Test the following systems:
  - a. All ducts with a pressure class lower than 6-inch WG: Test representative duct sections totaling no less than 25 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. Test for leaks before applying external insulation.
5. 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.
6. Give seven days' advance notice for testing.

- 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 according to "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.

- D. Duct system will be considered defective if it does not pass tests and inspections.

- E. Prepare test and inspection reports.

### 3.8 DUCT CLEANING

- A. Clean new and existing duct system(s) before testing, adjusting, and balancing.
- B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Division 23 Section "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.

C. 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.

D. 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.

E. 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 according to NADCA 1992. 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 according to manufacturer's written instructions after removal of surface deposits and debris.

### 3.9 START UP

- A. Air Balance: Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC."

### 3.10 DUCT SCHEDULE

- A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:
- B. Supply Ducts:
  - 1. Ducts Connected to all equipment:
    - a. Pressure Class: Positive up to 2-inch wg.
    - b. Minimum SMACNA Seal Class: A.
- C. Return Ducts:
  - 1. Ducts Connected to all equipment:
    - a. Pressure Class: Positive or negative up to 6-inch wg.
    - b. Minimum SMACNA Seal Class: A.
- D. Exhaust Ducts:
  - 1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:
    - a. Pressure Class: Negative up to 6-inch wg.
    - b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
- E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:
  - 1. Ducts Connected to all equipment:
    - a. Pressure Class: Positive or negative up to 3-inch wg.
    - b. Minimum SMACNA Seal Class: A.
- F. Ducts Connected to Equipment Not Listed Above or Relief/Transfer Air:
  - a. Pressure Class: Positive or negative 3-inch wg.
  - b. Minimum SMACNA Seal Class: A.
- G. Intermediate Reinforcement:
  - 1. Galvanized-Steel Ducts: Carbon steel coated with zinc-chromate primer.
  - 2. Stainless-Steel Ducts:
    - a. Exposed to Airstream: Match duct material.
    - b. Not Exposed to Airstream: Match duct material.
  - 3. Aluminum Ducts: Aluminum.
- H. Liner:
  - 1. Transfer Ducts: Fibrous glass, Type I, 1 inch thick.
- I. Elbow Configuration:
  - 1. As shown on drawings as either radius or mitered with turning vanes.
- J. Branch Configuration:

1. See drawings and Details sheets

**END OF SECTION**

## SECTION 23 31 19 - HVAC CASINGS

### PART 1 - GENERAL

#### 1.1 SUMMARY

A. Section Includes:

1. Shop-fabricated, field-assembled, single- and double-wall casings for HVAC equipment.

#### 1.2 PERFORMANCE REQUIREMENTS

A. Static-Pressure Classes:

1. Upstream from Fan(s): 4-inch wg negative.
2. Downstream from Fan(s): 4-inch wg positive.

B. Acoustical Performance:

1. NRC: 1.09 according to ASTM C 423.
2. STC: 40 according to ASTM E 90.

C. Structural Performance:

1. Casings shall be fabricated to withstand 133 percent of the indicated static pressure without structural failure. Wall and roof deflection at the indicated static pressure shall not exceed 1/8 inch per foot of width.
  - a. Fabricate outdoor casings to withstand wind load of 15 lbf/sq. ft. and snow load of 30 lbf/sq. ft..

#### 1.3 SUBMITTALS

A. Product Data: For each type of the following products:

1. Factory-fabricated casings.
2. Liners and adhesives.
3. Sealants and gaskets.
4. Seismic-restraint devices.

B. Shop Drawings: For HVAC casings. Include plans, elevations, sections, components, and attachments to other work.

1. Detail HVAC casing assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Sheet metal thickness(es).
3. Reinforcement and spacing.
4. Seam and joint construction.

5. Access doors including frames, hinges, and latches.
6. Filter, coil, humidifier, and other apparatus being installed in and mounted on casing.
7. Locations for access to internal components.
8. Hangers and supports including methods for building attachment, vibration isolation, and casing attachment.
9. Interior lighting, including switches.

C. Product Certificates: For acoustically critical casings, from manufacturer.

1. Show sound-absorption coefficients in each octave band lower than those scheduled when tested according to ASTM C 423.
2. Show airborne sound transmission losses lower than those scheduled when tested according to ASTM E 90.

D. Field quality-control reports.

#### 1.4 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports AWS D9.1M/D9.1, "Sheet Metal Welding Code," for casing joint and seam welding.

B. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
2. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for casing joint and seam welding.

C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

#### 1.5 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

B. Coordinate sizes and locations of steel supports. Supports are specified in Division 05 Section "Metal Fabrications."

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories."

## PART 2 - PRODUCTS

### 2.1 GENERAL CASING FABRICATION REQUIREMENTS

- A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 9, "Equipment and Casings," for acceptable materials, material thicknesses, and casing construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
  - 1. Fabricate casings with more than 4-inch wg negative static pressure according to SMACNA's "Rectangular Industrial Duct Construction Standards."
  - 2. Casings with more than 4-inch wg positive static pressure may be fabricated according to SMACNA's "Rectangular Industrial Duct Construction Standards."
  
- B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
  - 1. Exterior Surface Galvanized Coating Designation: G90.
  - 2. Interior Surface Galvanized Coating Designation:
    - a. Sections Not Exposed to Moisture: G90.
    - b. Sections Housing and Downstream from Cooling Coil and Humidifiers: G90.
  
- C. Stainless Steel: ASTM A 480/A 480M, Type 304, and having a No. 2D finish.
  
- D. Factory- or Shop-Applied Antimicrobial Coating:
  - 1. Apply to the interior sheet metal surfaces of casing in contact with the airstream. Apply untreated clear coating 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 according to ASTM D 3363.
  - 4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 according to UL 723; certified by an NRTL.
  - 5. Applied Coating Color: Standard.
  
- E. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.
  
- F. Sealing Requirement: SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Seal Class A. Seal all seams, joints, connections, and abutments to building.
  
- G. Penetrations: Seal all penetrations airtight. Cover with escutcheons and gaskets or fill with suitable compound so there is no exposed insulation. Comply with requirements for escutcheons specified in Division 23 Section "Escutcheons for HVAC Piping." Provide shaft seals where fan shafts penetrate casing.
  
- H. Access Doors: Fabricate access doors according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 9-15, "Casing Access Doors - 3-10-inch wg (750-2500 Pa)"; and according to pressure class of the plenum or casing section in which access doors are to be installed.
  - 1. Size: 18 by 54 inches, minimum.
  - 2. Vision Panel: Double-glazed, wire-reinforced safety glass with an airspace between panes and sealed with interior and exterior rubber seals.
  - 3. Hinges: Piano or butt hinges and latches, number and size according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
  - 4. Latches: Minimum of two wedge-lever-type latches, operable from inside and outside.

5. Neoprene gaskets around entire perimeters of door frames.
  6. Doors shall open against air pressure.
- I. Condensate Drain Pans: Formed sections of Type 200 series or 300 series, stainless-steel sheet complying with requirements in ASHRAE 62.1. Pans shall extend a minimum of 18 inches past coil.
1. Double-wall construction shall have space between walls filled with foam insulation and sealed moisture tight.
  2. Intermediate drain pan or drain trough shall collect condensate from top coil for units with stacked coils or stacked eliminators.
  3. Insulation: Polystyrene or polyurethane.
  4. Slopes shall be in a minimum of two planes to collect condensate from cooling coils (including coil piping connections and return bends), eliminators, and humidifiers when units are operating at maximum catalogued face velocity across cooling coil.
  5. Each drain pan connection shall have a trap. Include slab height in trap calculation.

## 2.2 SHOP-FABRICATED CASINGS

- A. Single- and Double-Wall Casings: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.
- B. Double-Wall Casing Inner Panel: Solid sheet steel. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.
- C. Interstitial Insulation: Polyurethane foam complying with NFPA 90A or NFPA 90B.
- or
- D. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
1. Maximum Thermal Value: R-12 or higher.
  2. Coat insulation with antimicrobial coating.
  3. Cover insulation with polyester film complying with UL 181, Class 1.
- E. Fabricate casings with standing seams and angle-iron reinforcements unless otherwise indicated.
- F. Fabricate close-off sheets from casing to dampers, filter frames, and coils and between stacked coils. Use galvanized sheet steel of same thickness as casing and with a galvanized coating designation of G90.
- G. Bolt close-off sheets to frame flanges and housings. Support coils on stands fabricated from galvanized-steel angles or channels.
- H. Reinforce casings with galvanized-steel angles.

## 2.3 MANUFACTURED CASINGS

- A. Description: Same as above for Shop fabricated.

## 2.4 CASING LINER

- A. Fibrous-Glass Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    - a. CertainTeed Corp.; Insulation Group.
    - b. Johns Manville.
    - c. Knauf Insulation.
    - d. Owens Corning.
  2. Thermal Conductivity:
    - a. Type I, Flexible: 0.15 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
    - b. Type II, Rigid: 0.12 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
  3. Antimicrobial Erosion-Resistant Coating: Apply to surface of the liner that will form the interior surface of casing to act as a moisture repellent and an erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
  4. Water-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.
    - a. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
    - b. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- B. Insulation Pins and Washers:
1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 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, stainless steel, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
- C. Shop or Factory Application of Casing 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 casing liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of casing 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 casings or cut and fit to ensure butted-edge overlapping.
  5. Apply adhesive coating on longitudinal seams in casings with air velocity of 2500 fpm.

6. 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.
7. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from casing wall. Fabricate edge facings at the following locations:
  - a. Fan discharges.
  - b. Intervals of lined casing preceding unlined duct.
  - c. Upstream edges of transverse joints in casings where air velocities are higher than 2500 fpm or where indicated.
8. Secure insulation between perforated sheet metal inner wall of same thickness as specified for outer wall. Use mechanical fasteners that maintain inner wall at uniform distance from outer wall without compressing insulation.

## 2.5 SEALANT MATERIALS

- 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 according to UL 723; certified by an NRTL.
- B. 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. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
  8. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
  9. Maximum Static-Pressure Class: 10-inch wg, positive or negative.
  10. Service: Indoor or outdoor.
  11. Substrate: Compatible with galvanized sheet steel or stainless steel.
  12. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

[Retain subparagraph below if required for LEED for Schools.](#)

13. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
  14. Maximum Static-Pressure Class: 10-inch wg, positive or negative.
  15. Service: Indoor or outdoor.
  16. Substrate: Compatible with galvanized sheet steel or stainless steel.
- C. Flanged Joint Sealant: Comply with ASTM C 920.
    1. General: Single component, acid curing, silicone, elastomeric.
    2. Type: S.

3. Grade: NS.
4. Class: 25.
5. Use: O.
6. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

D. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

### **PART 3 - EXECUTION**

#### **3.1 EXAMINATION**

- A. Examine concrete bases roof curbs and steel supports for compliance with requirements for conditions affecting installation and performance of HVAC casings.
- B. Examine casing insulation materials and liners before installation. Reject casings that are wet, moisture damaged, or mold damaged.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

#### **3.2 INSTALLATION**

- A. Install casings according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- B. Equipment Mounting: Install HVAC casings on concrete base. Comply with requirements for concrete base specified in Division 03 Section "Cast-in-Place Concrete."
  1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
  2. For supported casings, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
  3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
  4. Install anchor bolts to elevations required for proper attachment to supported equipment.
- C. Install seismic restraints on casings. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."
- D. Apply sealant to joints, connections, and mountings.
- E. Field-cut openings for pipe and conduit penetrations; insulate and seal according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- F. Support casings on floor or foundation system. Secure and seal to base.
- G. Support components rigidly with ties, braces, brackets, and anchors of types that will maintain housing shape and prevent buckling.

- H. Align casings accurately at connections, with 1/8-inch misalignment tolerance and with smooth interior surfaces.

### 3.3 FIELD QUALITY CONTROL

#### A. Tests and Inspections:

1. Perform field tests and inspections according to SMACNA's "HVAC Air Duct Leakage Test Manual."
2. Test the following systems:
  - a. Systems required by ASHRAE/IESNA 90.1.
3. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Give seven days' advance notice for testing.
4. Determine leakage from entire system or section of system by relating leakage to surface area of test section. Comply with requirements for leakage classification of ducts connected to casings.
5. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.

- B. HVAC casings will be considered defective if they do not pass tests and inspections.

- C. Prepare test and inspection reports.

### 3.4 CLEANING

- A. Comply with in Division 23 Section "Metal Ducts."

**END OF SECTION**

## SECTION 23 33 00 - AIR DUCT ACCESSORIES

### PART 1 - GENERAL

#### 1.1 SUMMARY

- A. Section Includes:
1. Manual volume dampers.
  2. Control dampers.
  3. Turning vanes.
  4. Duct-mounted access doors.
  5. Flexible connectors.
  6. Duct accessory hardware.

#### 1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.
1. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.
- B. 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 damper installations, including sleeves; and duct-mounted access doors and remote damper operators.
    - e. Duct security bars.
    - f. Wiring Diagrams: For power, signal, and control wiring.
- C. 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.
- D. Source quality-control reports.
- E. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

#### 1.3 QUALITY ASSURANCE

- 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 AMCA 500-D testing for damper rating.

## **PART 2 - PRODUCTS**

### **2.1 MATERIALS**

- A. 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.
- B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
  - 1. Galvanized Coating Designation: G90.
  - 2. Exposed-Surface Finish: Mill phosphatized.
- C. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.
- D. 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.

### **2.2 MANUAL VOLUME DAMPERS**

- A. Standard, Steel, Manual Volume Dampers:
  - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    - a. Air Balance Inc.; a division of Mestek, Inc.
    - b. Flexmaster U.S.A., Inc.
    - c. McGill AirFlow LLC.
    - d. METALAIRE, Inc.
    - e. Nailor Industries Inc.
    - f. Pottorff; a division of PCI Industries, Inc.
    - g. Ruskin Company.
  - 2. Ultra low leakage dampers are required..
  - 3. Suitable for horizontal or vertical applications.
  - 4. Frames:
    - a. Hat-shaped, galvanized-steel channels, 0.064-inch minimum thickness.
    - 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-steel, 0.064 inch thick.

6. Blade Axles: Galvanized steel.
7. Bearings:
  - a. Molded synthetic.
  - 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.

B. Jackshaft:

1. Size: 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.

C. 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.

## 2.3 CONTROL DAMPERS

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

1. Flexmaster U.S.A., Inc.
2. Greenheck Fan Corporation.
3. Lloyd Industries, Inc.
4. McGill AirFlow LLC.
5. METALAIRE, Inc.
6. Nailor Industries Inc.
7. Ruskin Company.
8. Young Regulator Company.

B. Ultra-Low-leakage rating and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.

C. Frames:

1. Hat or U or Angle shaped.
2. Galvanized-steel channels, 0.064 inch thick.
3. Mitered and welded corners.

D. Blades:

1. Multiple blade with maximum blade width of 8 inches.
2. Opposed-blade design.
3. Stainless steel.
4. 0.064 inch thick.
5. Blade Edging: Closed-cell neoprene edging.

6. Blade Edging: replaceable rubber seals.
- E. Blade Axles: 1/2-inch-diameter; stainless steel; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.
  1. Operating Temperature Range: From 0 to plus 200 deg F.
- F. Bearings:
  1. Molded synthetic.
  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.
- G. Actuators
  1. Fully modulating, see MI sheets, with differential pressure control tied to BAS system.
- H. Accessories:
  1. Auxiliary switches for signaling.
  2. Test and reset switches, damper mounted.

## 2.4 TURNING VANES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  1. Ductmate Industries, Inc.
  2. Duro Dyne Inc.
  3. METALAIRE, Inc.
  4. SEMCO Incorporated.
  5. Other acceptable manufacturers offering equivalent products.
- 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."
- E. Vane Construction: Double wall.
- F. Vane Construction: Single wall for ducts up to 24 inches wide and double wall for larger dimensions.

## 2.5 DUCT-MOUNTED ACCESS DOORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - 1. Flexmaster U.S.A., Inc.
  - 2. Greenheck Fan Corporation.
  - 3. McGill AirFlow LLC.
  - 4. Nailor Industries Inc.
  - 5. Pottorff; a division of PCI Industries, Inc.
  
- 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 internal insulation with similar R-value or higher than specified for external ductwork insulation and thickness as indicated for duct pressure class.
    - c. Hinges and Latches: piano hinge and cam latches.
    - d. Fabricate doors airtight and suitable for duct pressure class A.
  - 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 and two sash locks.
    - c. Access Doors up to 24 by 48 Inches: Three hinges and two compression latches.
    - d. Access Doors Larger Than 24 by 48 Inches: Four hinges and two compression latches with outside and inside handles.

## 2.6 DUCT ACCESS PANEL ASSEMBLIES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - 1. Ductmate Industries, Inc.
  - 2. Flame Gard, Inc.
  - 3. 3M.
  - 4. Other acceptable manufacturers offering equivalent products.
  
- B. Labeled according to UL 1978 by an NRTL.
  
- C. Panel and Frame: Minimum thickness 0.0428-inch **stainless** steel.
  
- D. Fasteners: 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.

## 2.7 FLEXIBLE CONNECTORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - 1. Ductmate Industries, Inc.
  - 2. Duro Dyne Inc.
  - 3. Ward Industries, Inc.; a division of Hart & Cooley, Inc.
- B. Materials: Flame-retardant or noncombustible fabrics.
- C. Coatings and Adhesives: Comply with UL 181, Class 1.
- D. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches wide attached to 2 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.
- 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: 0 to plus 200 deg F.
- 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.
- G. 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.

## 2.8 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.
- C. 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.
  - 1. Install steel volume dampers in steel ducts.
  - 2. Install aluminum volume dampers in aluminum ducts.
- D. Set dampers to fully open position before testing, adjusting, and balancing.
- E. Install test holes at fan inlets and outlets and elsewhere as indicated.
- F. 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 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.
  - 7. At each change in direction and at maximum 50-foot spacing.
  - 8. Upstream from turning vanes.
  - 9. Upstream or downstream from duct silencers.
  - 10. Control devices requiring inspection.
  - 11. Elsewhere as indicated.
- G. Install access doors with swing against duct static pressure.
- H. Label access doors according to Division 23 Section "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.
- I. Install flexible connectors to connect ducts to equipment.
- J. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

- K. Connect terminal units to supply ducts with maximum 12-inch lengths of flexible duct. Do not use flexible ducts to change directions.
- L. Connect flexible ducts to metal ducts with adhesive plus sheet metal screws.
- M. Install duct test holes where required for testing and balancing purposes.
- N. 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 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**

## SECTION 23 34 16 - CENTRIFUGAL HVAC FANS

### PART 1 - GENERAL

#### 1.1 SUMMARY

- A. Section Includes: For each product that is stand alone and not part of a rated piece of equipment.
1. Forward-curved centrifugal fans.
  2. Plenum fans.

#### 1.2 ACTION SUBMITTALS

- A. Product Data:
1. Include rated capacities, furnished specialties, and accessories for each fan.
  2. Certified fan performance curves with system operating conditions indicated.
  3. Certified fan sound-power ratings.
  4. Motor ratings and electrical characteristics, plus motor and electrical accessories.
  5. Material thickness and finishes, including color charts.
  6. Dampers, including housings, linkages, and operators.
- B. Shop Drawings:
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.
  4. Design Calculations: Calculate requirements for selecting vibration isolators and for designing vibration isolation bases.
  5. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

#### 1.3 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.
- B. Field quality-control reports.

#### 1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For centrifugal fans to include in emergency, operation, and maintenance manuals.

## PART 2 - PRODUCTS

### 2.1 PERFORMANCE REQUIREMENTS

- A. AMCA Compliance:
  - 1. Comply with AMCA performance requirements and bear the AMCA-Certified Ratings Seal.
  - 2. Operating Limits: Classify according to AMCA 99.
- 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.

### 2.2 FORWARD-CURVED CENTRIFUGAL FANS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - 1. Acme Engineering & Mfg. Corp.
  - 2. Greenheck.
  - 3. Loren Cook
  - 4. Twin City
- B. Description:
  - 1. Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and support structure.
  - 2. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations.
  - 3. Factory-installed and -wired disconnect switch.
- C. Housings:
  - 1. Formed panels to make curved-scroll housings with shaped cutoff.
  - 2. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
  - 3. Horizontally split, bolted-flange housing.
  - 4. Spun inlet cone with flange.
  - 5. Outlet flange.
- D. Forward-Curved Wheels:
  - 1. Black-enameled or galvanized-steel construction with inlet flange, backplate, shallow blades with inlet and tip curved forward in direction of airflow.
  - 2. Mechanically secured to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.
- E. Shafts:
  - 1. Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with adjustable alignment and belt tensioning.
  - 2. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.

3. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Pre-lubricated and Sealed Shaft Bearings:

1. Self-aligning, pillow-block-type ball bearings.
2. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
3. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

G. Grease-Lubricated Shaft Bearings:

1. Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
2. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
3. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.
4. .

H. Accessories:

1. Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.
2. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
3. Companion Flanges: Rolled flanges for duct connections of same material as housing.
4. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
5. Discharge Dampers: Assembly with opposed blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of airstream to single control lever of same material as housing.
6. Inlet Screens: Grid screen of same material as housing.
7. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
8. Spark-Resistant Construction: AMCA 99.
9. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
10. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.

## 2.3 PLENUM FANS

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

1. Aerovent; a Twin City Fan company.
2. Loren Cook Company.
3. Greenheck
4. Twin City
5. TEK

B. Description:

1. Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of wheel, fan shaft, bearings, motor, drive assembly, and support structure.
2. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations.
3. Factory-installed and -wired disconnect switch.

C. Airfoil Wheels:

1. Single-width-single-inlet construction with smooth-curved inlet flange.
2. Heavy backplate.
3. Hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate.
4. Cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

D. Shafts:

1. Statically and dynamically balanced and selected for continuous operation at maximum-rated fan speed and motor horsepower, with adjustable alignment and belt tensioning.
2. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
3. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

E. Pre-lubricated and Sealed Shaft Bearings:

1. Self-aligning, pillow-block-type ball bearings.
2. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
3. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

F. Grease-Lubricated Shaft Bearings:

1. Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
2. Ball-Bearing Rating Life: ABMA 9, L10 at 120,000 hours.
3. Roller-Bearing Rating Life: ABMA 11, L10 at 120,000 hours.

G. Accessories:

1. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
2. Spark-Resistant Construction: AMCA 99.
3. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.

## 2.4 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."
- B. Must be individually VFD'd or EC Motors. See drawings.

## 2.5 SOURCE QUALITY CONTROL

- A. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.

- B. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210/ASHRAE 51, "Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating."

### **PART 3 - EXECUTION**

#### **3.1 INSTALLATION**

- A. Install centrifugal fans level and plumb.
- B. Disassemble and reassemble units, as required for moving to the final location, according to manufacturer's written instructions.
  - 1. Lift and support units with manufacturer's designated lifting or supporting points. Install on 4-inch-high concrete base, curb mount or hung as shown on drawings. See below for each type of mounting.
- C. Equipment Mounting: Install centrifugal fans on cast-in-place concrete equipment base(s) using restrained spring isolators. Comply with requirements for equipment bases specified in Division 03 Section "Cast-in-Place Concrete." Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."
  - 1. Minimum Deflection: 1 inch.
  - 2. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
  - 3. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
  - 4. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floor.
  - 5. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
  - 6. Install anchor bolts to elevations required for proper attachment to supported equipment.
- D. Equipment Mounting: Install centrifugal fans using restrained spring isolators. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."
  - 1. Minimum Deflection: 1 inch.
- E. Equipment Mounting: Install centrifugal fans on vibration isolation equipment base. Comply with requirements specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."
- F. Equipment Mounting: Install continuous-thread hanger rods and spring hangers with vertical-limit stop of size required to support weight of dehumidification unit.
  - 1. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."
  - 2. Comply with requirements for hangers and supports specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."
- G. Curb Support: Install roof curb on roof structure, level and secure, according to "The NRCA Roofing and Waterproofing Manual," Low-Slope Membrane Roofing Construction Details Sec

tion, Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts." Install and secure centrifugal fans on curbs, and coordinate roof penetrations and flashing with roof construction. Secure units to curb support with anchor bolts.

- H. Unit Support: Install centrifugal fans level on structural curbs. Coordinate wall penetrations and flashing with wall construction. Secure units to structural support with anchor bolts.
- I. Isolation Curb Support: Install centrifugal fans on isolation curbs and install and vibration isolation and seismic-control devices.
  - 1. Comply with requirements in Division 23 Section "Air Duct Accessories" for flexible duct connectors.
  - 2. Comply with requirements in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for vibration isolation and seismic-control devices.
- J. Install units with clearances for service and maintenance.
- K. Label fans according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."

### 3.2 CONNECTIONS

- A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."
- B. Install ducts adjacent to fans to allow service and maintenance.
- C. Install piping from scroll drain connection, with trap with seal equal to 1.5 times specified static pressure, to nearest floor drain with pipe sizes matching the drain connection.

### 3.3 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
  - 1. Verify that shipping, blocking, and bracing are removed.
  - 2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
  - 3. Verify that cleaning and adjusting are complete.
  - 4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust.
  - 5. Adjust damper linkages for proper damper operation.
  - 6. Verify lubrication for bearings and other moving parts.
  - 7. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

8. See Division 23 Section "Testing, Adjusting, and Balancing For HVAC" for testing, adjusting, and balancing procedures.
  9. Remove and replace malfunctioning units and retest as specified above.
- C. Test and adjust controls and safeties. Controls and equipment will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.
- 3.4 DEMONSTRATION
- A. Train Owner's maintenance personnel to adjust, operate, and maintain centrifugal fans.

**END OF SECTION**

## SECTION 23 37 13 - DIFFUSERS, REGISTERS, AND GRILLES

### PART 1 - GENERAL

#### 1.1 SUMMARY

A. Section Includes:

1. Round ceiling diffusers.
2. Rectangular and square ceiling diffusers.
3. Perforated diffusers.
4. Louver face diffusers.
5. Fixed face registers and grilles.

B. Related Sections:

1. Division 08 Section "Louvers and Vents" for fixed and adjustable louvers and wall vents, whether or not they are connected to ducts.
2. Division 23 Section "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to diffusers, registers, and grilles.

#### 1.2 SUBMITTALS

A. Product Data: For each type of product indicated, include the following:

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, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

### PART 2 - PRODUCTS

#### 2.1 CEILING DIFFUSERS

All grilles registers and diffusers in stage area are to be flat black painted aluminum. All other grilles and diffusers in the project are to be standard aluminum white.

A. Round Ceiling Diffuser

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - a. METALAIRE, Inc.
  - b. Nailor Industries Inc.
  - c. Krueger.
  - d. Titus.
  - e. Price

2. Devices shall be specifically designed for variable-air-volume flows.
3. Material: Refer to Schedule.
4. Finish: Refer to Schedules.
5. Face Style: Four cone.
6. Pattern: Fully adjustable.

B. Rectangular and Square Ceiling Diffusers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - a. METALAIRE, Inc.
  - b. Nailor Industries Inc.
  - c. Krueger.
  - d. Titus.
  - e. Price.
2. Devices shall be specifically designed for variable-air-volume flows.
3. Material: Refer to schedules.
4. Finish: Refer to schedules.
5. Face Size: Refer to schedule.
6. Face Style: Three cone.
7. Mounting: Refer to schedule.
8. Pattern: Refer to schedules

C. Perforated Diffuser:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - a. METALAIRE, Inc.
  - b. Nailor Industries Inc.
  - c. Krueger.
  - d. Titus.
  - e. Price.
2. Devices shall be specifically designed for variable-air-volume flows.
3. Material: Refer to schedule.
4. Finish: Refer to schedules.
5. Face Size: Refer to schedule.
6. Mounting: Refer to schedule.

D. Louver Face Diffuser:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - a. METALAIRE, Inc.
  - b. Nailor Industries Inc.
  - c. Krueger.
  - d. Titus.
  - e. Price.
2. Devices shall be specifically designed for variable-air-volume flows.
3. Material: Refer to schedules.

4. Finish: Refer to schedules.
5. Face Size: Refer to schedule.
6. Mounting: Refer to schedule.

## 2.2 REGISTERS AND GRILLES

### A. Fixed Face Register:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - a. METALAIRE, Inc.
  - b. Nailor Industries Inc.
  - c. Krueger.
  - d. Titus.
  - e. Price.
2. Material: Refer to schedule.
3. Finish: Refer to schedule.
4. Face Arrangement: Perforated core.
5. Core Construction: Refer to schedule.
6. Frame: Refer to Schedule.
7. Mounting Frame: Refer to schedule.
8. Mounting: Refer to schedule.

### B. Fixed Face Grille:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
2. Basis-of-Design Product: Subject to compliance with requirements, provide or comparable product by one of the following:
  - a. METALAIRE, Inc.
  - b. Nailor Industries Inc.
  - c. Krueger.
  - d. Titus.
  - e. Price.
3. Material: Refer to schedule.
4. Finish: Refer to schedule.
5. Face Arrangement: Refer to schedules.
6. Core Construction: Refer to schedules.
7. Frame: Refer to specifications.
8. Mounting Frame: Refer to schedules.
9. Mounting: Refer to schedules.
10. Accessory: Filter. (Re: Schedule)

## 2.3 SOURCE QUALITY CONTROL

- A. Verification of Performance: Rate diffusers, 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 diffusers, registers, and grilles are to be 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, registers, and grilles 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, 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 diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

**END OF SECTION**

## SECTION 23 41 00 – PARTICULATE AIR FILTRATION

### PART 1 - GENERAL

#### 1.1 SUMMARY

- A. This Section includes factory fabricated air filter devices and media utilized to remove particulate matter and gaseous contaminants in HVAC applications.

#### 1.2 DEFINITIONS

- A. ASHRAE – American Society of Heating, Refrigeration and Air Conditioning Engineers
- B. IEST – Institute of Environmental Sciences and Technology
- C. UL – Underwriters Laboratories
- D. MERV – Minimum Efficiency Reporting Value per ASHRAE Standard 52.2 - Method of Testing General Ventilation Air Cleaning Devices for Removal by Particle Size
- E. Atmospheric Dust Spot Efficiency – per ASHRAE Standard 52.1 – Gravimetric and Dust Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter. Information deleted as this Standard was closed by ASHRAE in 2008.
- F. DOP – Dioctyl Phthalate, a carcinogen that was part of the original military-defined process of testing HEPA filters, no longer used to evaluate filters. Where noted, HEPA/ULPA filters should be evaluated using polystyrene latex spheres (PSL).
- G. HEPA – High-Efficiency Particulate Air Filter, a filter with a factory confirmed efficiency of no less than 99.97% when evaluated on particles 0.3 microns in size.
- H. ULPA – Ultra Low Penetration Air Filter, a filter with a factory confirmed efficiency of no less than 99.9995% when evaluated on particles 0.12 microns in size.
- I. HEPA – High Efficiency Gas Adsorber, box-style filter with a removal rate on specified contaminants exceeding 95%.

#### 1.3 SUBMITTALS

- A. Product Data: Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; UL classification; furnished specialties; and accessories for each model indicated. Manufacturers' literature and sales drawings acceptable.
- B. Shop Drawings: Include plans, elevations, sections, and details to illustrate component assemblies and attachments.
- C. Show filter holding mechanism assembly, dimensions, materials and methods of installation and sealing in drawings.

- D. Include setting drawings, templates and requirements for installing anchor bolts and anchorages.
- E. Operation and Maintenance Data: For each type of filter and filter holding mechanism to include in emergency, operation and maintenance manuals.

#### 1.4 QUALITY ASSURANCE

- A. Product Options: Drawings indicate size, profiles and dimensional requirements of air filter and are based on the specific system indicated. Refer to Division 01 Section "Product Requirements."
- B. Comply with ARI 850.
- C. Comply with UL 900 for ASHRAE grade filters and UL 900 for HEPA/ULPA filters.
- D. Comply with ASHRAE Standard 52.2 where applicable, and IEST Recommended Practices for HEPA/ULPA filters.
- E. Comply with NFPA 70 for installing electrical components.
- F. Comply with NFPA 90A and NFPA 90B.

#### 1.5 EXTRA MATERIALS

- A. Furnish extra materials below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. Refer to Paragraph 2.12, Temporary and Construction Filters.

### **PART 2 - PRODUCTS**

#### 2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:
  - 1. American Air Filter
  - 2. Koch Filter Corporation.
  - 3. Camfil Farr
  - 4. Filtration Group
  - 5. Flanders/Precisionaire/CSC Corp.

#### 2.2 PREFILTERS AND PRIMARY FILTERS – EFFICIENCY – MERV 13

- A. Air handling equipment shall not be operated without filters installed (ex: see roughing filter section). Minimum efficiency during normal operation shall be no less than MERV 13.

- B. The filter shall have a minimum efficiency reporting value of MERV 13 when evaluated under the guidelines of ASHRAE Standard 52.2. It shall have a MERV-A of 13 when evaluated under Appendix J of the same Standard.
- C. Each filter shall consist of a cotton and synthetic blend media, a welded wire media support grid and a high wet-strength beverage board enclosing frame. The filter shall be listed by Underwriters' Laboratories as UL Class 2.
- D. The filter media area and initial resistance shall be:
  - For a 2" deep filter                      Maximum 0.21" w.g.
  - For a 4" deep filter                      Maximum 0.27" w.g.

2.3 ROUGHING FILTERS – MERV 13

- A. Roughing prefilters shall be medium efficiency, extended area, disposable type of the quantity and size indicated on the drawings.
- B. The filter media shall have a minimum efficiency reporting value of MERV 13 when evaluated under the guidelines of ASHRAE Standard 52.2. It shall have a MERV-A of 13 when evaluated under Appendix J of the same Standard.
- C. The filter shall be listed by Underwriter Laboratories as Class 2.

2.4 SECONDARY FILTERS – MINI-PLEAT 4" DEEP TYPE EFFICIENCY MERV 13, AS NOTED ON DRAWINGS

- A. Air filters shall be 4" deep high efficiency ASHRAE box style filters consisting of mini-pleated wet laid fine fiber media, thermoplastic resin separators, frame to media adhesive and high wet strength beverage board enclosing frame.
- B. Filter media shall be of one continuous sheet of microfine wet-laid glass mat filter media formed into uniformly spaced pleats and formed into a mini-pleat pack configuration. Thermoplastic pleat separators shall provide uniform media separation to promote uniform airflow throughout the media. The enclosing frame shall be of high wet strength beverage board which shall be bonded to the entire periphery of the media pack to prevent air bypass. The frame shall include integral diagonal support members to ensure maintained media spacing and pleat stability. The diagonal support members shall be bridge-engineered to prevent filter racking and ensure filter configuration integrity. Filter shall be bi-directional with regard to airflow.
- C. The filter shall have a Minimum Efficiency Reporting Value of MERV (as scheduled)\* when evaluated under the guidelines of ASHRAE Standard 52.2. It shall have a MERV-A of (as scheduled)\* when evaluated under Appendix J of the same Standard.
- D. Initial resistance to airflow shall be (0.27")\* w.g at an airflow of 500 fpm. Manufacturer shall provide evidence of facility certification to ISO 9001:2000. The filter shall be capable of withstanding 5" w.g. without failure of the media pack.
- E. Performance of the filter shall comply with the following minimum performance data based on a 24" by 24" by 4" filter tested at 2000 CFM.
- F. Supporting Data - Provide a product test report for each listed efficiency including all details as prescribed in ASHRAE Standard 52.2 including Appendix J.

## 2.5 UNIVERSAL ASHRAE GRADE HOLDING FRAMES

- A. Holding Air filter holding frames shall be 16-gauge galvanized steel with filter sealing flange, centering dimples, sealing gasket and lances for appropriate air filter fasteners. Sizes shall be noted on drawings or other supporting materials. Filter holding frame shall be constructed of 16-gauge galvanized steel. The frame shall be assembled from two corner sections and welded to assure a rigid and durable frame assembly. The frame shall include a variety of pre-punched lances for filter fastener attachment. Fastener shall be capable of being installed without the use of tools, nuts or bolts. Lance penetrations shall be upstream of filter flange to assure leak-free integrity. The frame shall include filter centering dimples on each frame wall to facilitate ease of filter installation and assure filter centering against filter sealing flange. A 3/4" filter sealing flange shall be an integral component of the holding frame. All corners shall be flush mitered and a permanently mounted polyurethane foam gasket shall be mounted on the sealing flange to assure filter to frame sealing integrity. Manufacturer shall provide evidence of facility certification to ISO 9001:2000.
- B. The appropriate fastener, as recommended by the manufacturer, shall secure each filter at its corner (four (4) fasteners per filter).
- C. Holding Frames shall be assembled to form built-up filter banks with the use of nuts and bolts and vertical support members as detailed on manufacturer provided drawings.
- D. Dow 732 Sealant shall be applied to the periphery of all Holding Frames prior to clamping, assembly and bolting.

## 2.6 FIELD QUALITY CONTROL

- A. Contractor to engage a factory authorized service representative to inspect [, test and adjust] field assembled components, inspect filters, filter frames and filter housing installations. Documented results of inspection to be provided to engineer in charge.
- B. HEPA Filter Housings: Pressurize housings to a minimum of 3.0" w.g. (750 Pa) 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.

## 2.7 CLEANING

- A. After completing system installation and testing, adjusting, and balancing air-handling and air-distribution systems, clean filter housings and install new filter media.

**END OF SECTION**

## SECTION 23 7312 – SEMI CUSOM OUTDOOR AIR HANDLING UNITS

### PART 1 - GENERAL

#### 1.1 QUALITY ASSURANCE

- A. Manufacturer Qualifications:  
Company specializing in manufacturing the products specified in this section with minimum of 5 years documented experience.
- B. The management system governing the manufacture of this product is ISO (International Organization for Standardization) 9001:2015 certified.
- C. Air-handling unit assembly shall have UL (Underwriters Laboratories) 1995 certification for safety, including use with electric heat.
- D. Products requiring electric connection shall be listed and classified by ETL and CSA (Canadian Standards Association) as suitable for the purpose specified and indicated.
- E. All coils shall be rated in accordance with AHRI Standard 410, latest edition. Chilled water, hot water, and steam coils shall be certified, in accordance with AHRI Standard 410.
- F. Direct expansion coils shall be designed and tested in accordance with ANSI/ASHRAE (American National Standard Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers) 15 Safety Code for Mechanical Refrigeration.
- G. Unit performance shall be rated in accordance with AHRI Standard 430 for Central Air Handling Units and subject to verification of rating accuracy by AHRI-sponsored, third party testing. Units shall meet NFPA (National Fire Protection Association) 90A requirements.

#### 1.2 DELIVERY, STORAGE AND PROTECTION

- A. All outdoor units shall be completely shrink-wrapped from the factory for protection during shipment. Tarping of bare units is unacceptable.
- B. Inspect for transportation damage and store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish.

#### 1.3 START-UP REQUIREMENTS

Do not operate units until ductwork is clean, filters are in place, bearings lubricated, condensate properly trapped, piping connections verified, and leak tested, belts aligned and tensioned, all shipping braces have been removed, and fan has been test run under observation.

### PART 2 – PRODUCTS

#### 2.1 GENERAL DESCRIPTION

- A. Units shall ship in the number of sections necessary to meet project requirements and shall ship in as many splits as specified in selection software. Split options as follows:
  - 1. Shipped in sections — shipping split.
  - 2. Shipped assembled — solid base rail.
- B. Unit shall be factory-supplied, factory-assembled. The air-handling unit may consist of a fan with the following factory-installed components as indicated on the equipment schedule.
  - 1. Mixing Box Sections:
    - a. No filter tracks.
    - b. With motorized dampers on both air streams per code or can be in duct connections.
  - 2. Plenum Sections:

- a. No drain pan.
3. Draw-Thru Discharge Plenum.
4. Filter Section:
  - a. 2-in. angle filters.
5. Coil Section:
  - a. Direct expansion coil.
6. Fan Section:
  - 1.2 Horizontal draw-thru.

## 2.2 CASING

### A. Construction:

1. Unit shall be constructed of a complete frame with easily removable panels. Removal of any panel shall not affect the structural integrity of the unit.
2. All units shall be supplied with a perimeter, 14-gage or heavier, G-90 galvanized, high tensile steel base rail. Perimeter lifting lugs for overhead lifting shall be provided on each shipping section. Slings units in place of lifting lugs shall not be acceptable.
3. Unit shall be thermally broken to minimize the conduction path from the inside of the casing to the outside.
4. Casing panels (top, sides, and bottom) shall be constructed of galvanized steel (18 gauge), and shall have one of the following exterior finishes as specified:
  - a. Pre-painted with a baked enamel finish passing 500-hour salt spray test (ASTM [American Society of Mechanical Engineers] B-117) for pre-painted steel and 125-hour marine level 1 prohesion test (ASTM G-85.A5) for pre-painted steel.
  - b. Unpainted G-90 galvanized steel.
5. Casing panels (top, sides, and bottom) shall be constructed of galvanized or stainless steel (18 gauge optional), and shall have one of the following interior finishes as specified:
  - a. Pre-coated galvanized steel with a silver zeolite antimicrobial material registered by the US EPA (Environmental Protection Agency) for use in HVAC applications.
6. Casing panels (top, sides, and bottom) shall be one piece double-wall construction with insulation sealed between the inner and outer panels. Panel assemblies shall not carry an R-value of less than 12.
7. Casing deflection shall not exceed an L/240 ratio when subject to an internal pressure of  $\pm 8$ -in. wg and shall exhibit no permanent deformation at  $\pm 9$  in. wg L is defined as the longest linear panel or cabinet length (measured to AHRI 1350 Cd level 2).
8. Casing leakage rate shall be less than 1% at  $\pm 8$  in. wg of nominal unit airflow or 50 cfm, whichever is greater. Factory test reports shall be available.
9. Side panels shall be easily removable for access to unit and shall seal against a full perimeter automotive style gasket to ensure a tight seal.
10. The panel retention system shall comply with UL 1995 which states all moving parts (for example, fan blades, blower wheels) that, if accidentally contacted, could cause bodily injury, shall be guarded against accidental contact by an enclosure requiring tools for removal.
11. Accessibility options shall be as follows:

- a. Hinged, lockable double-wall access door on either side with removable access panel(s) on the other side. See drawings.
12. Inside each section, the following shall be provided if shown on drawings:
    - a. Reinforced glass viewports shall be factory-installed on the access panel(s) or door(s) of this section.
    - b. Marine lights shall be factory-installed with GCFI (ground fault circuit interrupter) convenience outlets.
  13. Fan supports, structural members, panels, or flooring shall not be welded. Painted welds on unit exterior steel or galvanized steel are not acceptable.
  14. All coil sections shall be double-wall construction with foam insulation sealed between the inner and outer panels. Panel assemblies shall not carry an R-value of less than 13.
- B. Access Doors:  
Access doors shall be one piece, hinged, lockable, double-wall construction with foam insulation sealed between the inner and outer panels. Panel assemblies shall not carry an R-value of less than 12. Access doors shall also have low leakage seals on all closing surfaces.
- C. Drain Pans:  
Drain pans shall be insulated double-wall stainless steel construction (18 gauge). The pan shall be sloped toward the drain connection. Drain pan shall have 1<sup>1</sup>/<sub>2</sub>-in. MPT connection exiting through the hand side of the casing as shown on drawings. Drain connection shall be insulated from the drain pan to the point at which it exits the casing. One drain outlet shall be supplied for each cooling coil section. Drain pan shall allow no standing water and comply with ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) Standard 62.1-2010. Where 2 or more coils are stacked in a coil bank, intermediate drain pans shall be provided, and the condensate shall be piped to the bottom drain pan. The bottom coil shall not serve as a drain path for the upper coil.

## 2.3 FANS

### A. General:

1. Direct drive plenum fan sections shall have the option of one, two, four, or six single width single inlet (SWSI) airfoil fan wheel(s). Airfoil blades shall be double thickness design continuously welded to the back plate and the front plate. Fan wheel shall be constructed of aluminum. Airfoil blades shall be aluminum extrusions and shall be top welded to the back plate and front plate of the wheel. Fan wheel shall be dynamically balanced per ISO standard 1940 quality grade G6.3.
2. Fan assembly vibration shall not exceed 0.248 in. per second when mounted on active isolators. Vibration shall be measured in both vertical and horizontal directions at the specified fan operating speed using specified motor. For testing purposes, accelerometers shall be mounted on the motor near the bearing locations and removed before shipment.
3. All fan sled components shall provide corrosion protection to pass 100-hour salt spray test per ASTM B-117.
4. Fan wheels shall be keyed to the shaft and shall be designed for continuous operation at maximum rated fan speed and motor horsepower. Fan wheels and shafts shall be selected with a maximum operating speed 25% below the first critical.

### B. Performance Ratings:

Fan performance shall be rated and certified in accordance with AHRI Standard 430.

### C. Sound Ratings:

Manufacturer shall submit first through eighth octave sound power for fan discharge and casing radiated sound. Sound ratings shall be tested in accordance with AHRI 260.

D. Mounting:

Fan scroll, wheel, shaft, bearings, drives, and motor shall be mounted on a common base assembly. The base assembly is isolated from the outer casing with factory-installed isolators and vibration absorbent an discharge seal. A canvas style duct connection between fan discharge and cabinet is not acceptable. Units shall use 2-in. deflection spring isolators.

E. Fan Accessories:

1. Direct Drive Plenum Fans:

- a. Variable frequency drives.
- b. Motor protection box for motor current protection with a single VFD driving multiple motors.
- c. Airflow measuring piezo ring.
- d. Piezo ring transducer.
- e. Motor shaft grounding ring.
- f. Inlet guard.
- g. Blank off plate.
- h. Backdraft Dampers

Backdraft damper blades shall be 6063-T5 extruded aluminum channel with galvanized steel braces and extruded vinyl blade seals. Blades shall be mechanically fastened to axle rods rotating in corrosion-resistant synthetic bearings. Blades begin to open at 0.12 in. wg and are fully open at 0.2 in. wg.

F. Flexible Connection:

The base assembly is isolated from the outer casing with factory-installed isolators and vibration absorbent fan discharge seal. A canvas style duct connection between fan discharge and cabinet is not acceptable.

2.4 BEARINGS AND DRIVES

A. Bearings:

Self-aligning, grease lubricated, anti-friction with lubrication fittings extended to drive side of fan section. Optional grease fittings extended to the exterior of the casing are available. All bearing life calculations shall be done in accordance with ABMA 9 for ball bearings and ABMA 11 for roller bearings.

1. Direct drive plenum fans: Heavy-duty pillow block type, self-aligning, regreasable roller type bearings selected for a minimum average life (L50) of 200,000 hours or optionally for an (L50) of 500,000 hours.

2.5 COILS

- A. All direct expansion (DX) refrigerant coils shall be provided to meet the scheduled performance. All coil performance shall be certified in accordance with AHRI Standard 410. All water and direct expansion coils shall be tested at 450 psig air pressure. Direct expansion coils shall be designed and tested in accordance with ANSI/ASHRAE 15 Safety Code for Mechanical Refrigeration (latest edition). Factory-supplied  $\frac{1}{2}$ -in. OD coils shall be covered under the standard product one-year limited warranty. All steam coils, integral face and bypass coils and  $\frac{5}{8}$ -in. OD coils shall be warranted for a period not in excess of 12 months from their shipment from the manufacturer. Coil epoxy coating shall be covered under a 5-year limited warranty from the date of shipment from the manufacturer.

B. General Fabrication:

1. All refrigerant coils shall have minimum  $\frac{1}{2}$ -in. OD copper tubes mechanically expanded into fins to ensure high thermal performance with lower total flow and pumping requirements. Minimum tube wall thickness shall be 0.025 in.
2. Aluminum plate fin type with belled collars.

3. Aluminum-finned coils shall be supplied with die-formed casing and tube sheets of stainless steel as specified..

F. Refrigerant Coils:

1. Headers shall be constructed of copper with brazed joints.
2. Brass refrigerant distributors and seamless copper distribution tubes shall be factory supplied to ensure uniform flow.
3. Thermal expansion valves (TXV) and nozzles shall be factory installed and piped to the exterior of the casing. Equalizer lines shall be piped internal to the coil header.
4. Suction and liquid line pairs shall be located next to each other for easy circuit identification. A custom label showing TXV size, nozzle size and condensing unit circuit pairing shall be located on the side of the coil section.
5. Standard circuiting selections include:
  - a. Row split intertwined multiple distributor arrangement.
6. Submittals must include a DX coil and condensing unit cross plot to show that the coil and condensing unit capacity match at the rated design conditions.

2.6 FILTER SECTIONS

- A. Flat filter sections shall accept either 2-in. or 4-in. filters. Sections shall include side access slide rails. Optional 2 in. pre-filter shall be provided.

2.7 DAMPERS

- A. Factory-supplied dampers shall be warranted to be free from defects in material and workmanship for a period of 12 months after being installed or placed in service, but in no instance shall the period of warranty be longer than 18 months from the date of the original shipment by the manufacturer.
- B. Mixing boxes, filter-mixing boxes, and exhaust boxes shall have parallel or opposed blades and be independently actuated.

1. Return Dampers:

Damper blades shall be constructed of galvanized steel with a double-skin airfoil design, with blade seals and stainless-steel jamb seals. Blades shall be mechanically fastened to axle rods rotating in self-lubricating synthetic bearings. Maximum leakage rate shall be 2 cfm/ft<sup>2</sup> at 1 in. wg differential pressure.

2. Outside Air Dampers:

- a. Damper frame shall be nominal 4 in. x 1 in. x minimum 0.081 in. and constructed of 6063-T5 extruded aluminum.
- b. Airflow measuring blades shall be airfoil-shaped, heavy gage anodized 6063-T5 extruded aluminum and fixed in 10 in. x minimum 16 gage galvanized steel frame.
- c. Jamb seals shall be flexible metal compression type along control damper sides.
- d. Blade seals shall be neoprene along control damper blade edges.
- e. Bearings shall be molded synthetic.
- f. Linkage shall be stainless steel, concealed in frame.
- g. Axles shall be minimum 1/2-in. diameter plated steel, hex-shaped, mechanically attached to blade.
- h. Operating temperature shall be -22 to 140°F.
- i. Maximum leakage rate shall be 2 cfm/ft<sup>2</sup> at 1 in. wg differential pressure.

2.8 ELECTRICAL ACCESSORIES

A. Single Point Power:

The single point power (SPP) box shall have an externally mounted, complete unit line of site disconnect. Internally, the single point power box shall have individual circuit breakers for each circuit,

allowing individual circuit protection and a means of disconnect while not completely disabling the unit. Single Point Power Enclosure:

- a. Enclosure supplied shall have appropriately sized circuit breakers, fusing, wiring, labeling and penetrations based on the unit configuration.
  - b. Enclosure shall be equipped with a lockable door and a NEMA extended rotary handle mechanism on the enclosure door to provide a means for external disconnect operation to the main circuit breaker switch within the SPP enclosure.
  - c. Enclosure to be NEMA 1 steel or equivalent.
  - d. All SPP assemblies shall comply with UL 508 and be labeled as compliant.
  - e. Wiring penetrations shall be pre-punched in the back of the enclosure and enter the inside of the air handling unit through strain reliefs. Enclosure shall be gasketed and sealed to the panel it is mounted to.
  - f. A single 120 volt GFCI outlet shall be mounted on the enclosure when at least one marine light, convenience outlet, UV-C section or controls section is selected.
  - g. Internal components (i.e., fuse blocks, circuit breakers) shall be labeled with the appropriate circuit identification.
  - h. Enclosure assemblies supplied with fuses shall have a label affixed that provides replacement fuse identification.
  - i. All enclosures shall have the following labels adhered to the inside of the enclosure door: UL 508 labeling, amperage and voltage rating, maximum overcurrent protection rating.
1. Transformer:
    - a. Single phase resin filled.
    - b. Low voltage transformer to be Square D or equivalent.
    - c. NEMA 3R enclosure rating.
      - 1) 208/220 or 440 volt primary to 110/220 volt secondary 60 Hz.
    - d. All unit controls shall be BACNet compatible with the BAS intended to be used and the VRF units the AHU's are connected to.
  2. Wiring and Harnesses:
    - a. Wiring harnesses shall be specifically designed for the unit configuration. Generic wiring harnesses are not acceptable.
    - b. Wire assemblies shall be thermoplastic heat resistant nylon coated (THHN) stranded copper (90°C) or AWM wire. All wires used shall be moisture resistant. Conductors shall be bundled and sleeved with heat-shrink material over connector end and sleeve. All colored electrical tape for wire marking shall be "3M Super 35 electrical tape". For readability, laser print to be black on white background, smudge and wear resistant for life of wire assembly. The crimping of contactors to wires and the assembly of connectors to contactors shall follow manufacturer's instructions.
    - c. Wiring harnesses shall have polarized plugs that can only be assembled one way. Plugs shall have the ground lug identified by a green connector, while all of the powered lugs shall be black.
    - d. If a shipping split is inserted in the unit configuration, a label shall instruct the assembler to connect the single point wiring harness before the two unit sections are mated. Each wiring harness shall extend at least 12 in. from each shipping split to allow the harnesses to be mated.
- C. Disconnects:  
Factory-supplied disconnects shall be covered under a 1-year limited warranty from the manufacturer from the date of shipment.
- E. External Bypass for Variable Frequency Drives:

Factory-supplied bypasses shall be covered under a 1-year limited warranty from the manufacturer from the date of shipment.

- a. See VFD specification for details.

**END OF SECTION 23 73 12**

## **SECTION 23 81 27 – VRF SPLIT-SYSTEM AIR-CONDITIONERS**

### **PART 1 - GENERAL**

#### **1.1 SYSTEM DESCRIPTION**

The variable capacity, heat pump or heat recovery system as scheduled on drawings shall be a Variable Refrigerant Flow or Variable Refrigerant Volume zoning system. The system approach may be either 2 pipe or 3 pipe as long as design intent shown in the drawings is met

The system shall consist of a outdoor unit, RC Refrigerant Controller or BS Branch Selector, multiple indoor units, and DDC (Direct Digital Controls) that are BACNet compatible. Each indoor unit or group of indoor units shall be capable of operating in the same mode as other units attached to the same condenser. System shall be capable of changing mode (cooling to heating, heating to cooling) with no interruption to system operation. To ensure owner comfort, each indoor unit or group of indoor units shall be independently controlled

#### **1.2 QUALITY ASSURANCE**

- A. The units shall be listed by Electrical Testing Laboratories (ETL) and bear the ETL label.
- B. All wiring shall be in accordance with the National Electrical Code (N.E.C.).
- C. The units shall be manufactured in a facility registered to ISO 9001 and ISO14001 which is a set of standards applying to environmental protection set by the International Standard Organization (ISO).
- D. All units must meet or exceed the efficiency requirements in the most current version of ASHRAE 90.1 for VRF systems. Efficiency shall be published in accordance with the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Standard 1230.
- E. A full charge of low GWP refrigerant for the condensing unit only shall be provided in the condensing unit. All outdoor and indoor units shall be compatible with the same refrigerant.

#### **1.3 DELIVERY, STORAGE AND HANDLING**

- A. Unit shall be stored and handled according to the manufacturer's recommendation.

#### **1.4 CONTROLS**

- A. The control system shall consist of a low voltage communication network of unitary built-in controllers with on-board communications and a web-based operator interface. A web controller with a network interface card (BACNet compatible) shall gather data from this system and generate web pages accessible through a conventional web browser on each PC connected to the network. Operators shall be able to perform all normal operator functions through the web browser interface.
- B. System controls and control components shall be installed in accordance with the manufacturer's written installation instructions.
- C. Furnish energy conservation features such as optimal start, night setback, request-based logic, and demand level adjustment of overall system capacity as specified in the sequence.

- D. System shall provide direct and reverse-acting on, and off algorithms based on an input condition or group conditions to cycle a binary output or multiple binary outputs.
- E. Provide capability for future system expansion to include monitoring and use of occupant card access, lighting control and general equipment control.
- F. The system shall be capable of email generation for remote alarm annunciation.
- G. Control system start-up shall be a required service to be completed by the manufacturer or a duly authorized, competent representative that has been factory. The representative shall provide proof of certification for Electric Controls Applications Training indicating successful completion of no more than two (2) years prior to system installation. This certification shall be included as part of the equipment and/or controls submittals. This service shall be equipment and system count dependent and shall be a minimum of two (2) eight (8) hour period to be completed during normal working hours with one being at occupation and the other being at 6 months after occupation of the facility.

## **PART 2 – WARRANTY**

- 2.1 The units shall be covered by the manufacturer's limited warranty for a period of ten (10) years to the original owner from date of installation.

This warranty shall not include labor but labor by the installer shall be covered for a period of one year after substantial completion.

- 2.2 All manufacturer technical and service manuals must be readily available for download by any local contractor should emergency service be required. Registering and sign-in requirements which may delay emergency service reference are not allowed.

## **PART 3 – PRODUCTS**

### **3.1 OUTDOOR UNIT**

#### **A. General:**

The outdoor unit shall be used specifically with the indoor corresponding components shown and scheduled in the drawings. Each outdoor unit module shall be completely factory assembled, piped and wired and run tested at the factory.

1. Outdoor unit shall have a sound rating no higher than 60 dB(A) individually or 64 dB(A) twinned. Indoor Units shall have a sound rating no higher than 50 dB(A) individually or 53 dB(A) twinned while in night mode operation. If an alternate manufacturer is selected, any additional material, cost, and labor to meet published sound levels shall be incurred by the contractor.
2. All refrigerant lines from the outdoor unit to the RC Controller (Single or Main) shall be insulated in accordance with the installation manual.
3. Outdoor unit shall be able to connect to up to 50 or more indoor units.
4. The outdoor unit shall have an accumulator with refrigerant level sensors and controls.
5. The outdoor unit shall have a high-pressure safety switch, over-current protection, crankcase heater and DC bus protection.

6. The outdoor unit shall have the ability to operate with a maximum height difference of 150 feet and have total refrigerant tubing length of 1000 feet. The greatest length is not to exceed 500 feet between outdoor unit and the indoor units without the need for line size changes or traps.
7. The outdoor unit shall be capable of operating in heating mode down to -4°F ambient temperatures or cooling mode down to 23°F ambient temperatures, without additional low ambient controls. If an alternate manufacturer is selected, any additional material, cost, and labor to meet low ambient operating condition and performance shall be incurred by the contractor.
8. The outdoor unit shall be capable of operating in cooling mode down to -10°F with optional manufacturer supplied low ambient kit.
9. The manufacturer supplied low ambient kit shall be provided with predesigned control box rated for outdoor installation and capable of controlling kit operation automatically in all outdoor unit operation modes.
10. The manufacturer supplied low ambient kit shall be listed by Electrical Laboratories (ETL) and bear the ETL label.
11. The manufacturer supplied low ambient kit shall be factory tested in low ambient temperature chamber to ensure operation. Factory performance testing data shall be available when requested.
12. The outdoor unit shall have a high efficiency oil separator plus additional logic controls to ensure adequate oil volume in the compressor is maintained.
13. Unit must defrost all circuits simultaneously in order to resume full heating more quickly.

B. Unit Cabinet:

1. The casing(s) shall be fabricated of galvanized steel and finished. to withstand 960 hours per ASTM B117 criteria for seacoast protected

C. Fan:

1. Each outdoor unit module shall be furnished with one direct drive, variable speed propeller type fan. The fan shall be factory set for operation under 0 in. WG external static pressure, but capable of normal operation under a maximum of 0.24 in. WG external static pressure.
2. All fan motors shall have inherent protection, have permanently lubricated bearings, and be completely variable speed.
3. All fan motors shall be mounted for quiet operation.
4. All fans shall be provided with a raised guard to prevent contact with moving parts.

D. Refrigerant

1. Low GWP refrigerant shall be required outdoor unit systems.

E. Coil:

1. The outdoor coil shall be of nonferrous construction with lanced or corrugated plate fins on copper tubing.
2. The coil fins shall have a factory applied corrosion resistant finish.
3. The coil shall be protected with an integral metal guard.
4. Refrigerant flow from the outdoor unit shall be controlled by means of an inverter driven compressor.

F. Compressor:

1. Each outdoor unit module shall be equipped with one inverter driven scroll hermetic compressor. Non-inverter-driven compressors, which cause inrush current (demand charges) and require larger wire sizing, shall not be allowed.
2. A crankcase heater(s) shall be factory mounted on the compressor(s).
3. The outdoor unit compressor shall have an inverter to modulate capacity. The capacity shall be completely variable with a turndown to 5% of rated capacity, depending upon unit size.
4. The compressor will be equipped with an internal thermal overload.
5. The compressor shall be mounted to avoid the transmission of vibration.
6. Field-installed oil equalization lines between modules are not allowed. Prior to bidding, manufacturers requiring equalization must submit oil line sizing calculations specific to each system and module placement for this project.

G. Controls:

1. The outdoor unit shall have the capability of up to 8 levels of demand control for each refrigerant system

H. Electrical:

1. The outdoor unit shall be controlled by integral microprocessors.
2. The control circuit between the indoor units, RC Controller and the outdoor unit shall be 24VDC completed using a 2-conductor, twisted pair shielded cable to provide total integration of the system.

I. Coating:

1. The outdoor unit shall be tested in compliance with ISO9277 such that no unusual rust shall develop after 960 hours of salt spray testing.
2. The outdoor unit shall be open to the elements such that rain will wash away salt residue.
3. The outdoor unit shall be installed in such a way as to achieve optimal drainage.

### 3.02 REFRIGERANT CIRCUIT (RC/BS) CONTROLLERS

#### A. General

The RC/BS Controllers shall include multiple branches to allow simultaneous heating and cooling by allowing refrigerant to flow to indoor unit(s) for heating or refrigerant to flow to indoor unit(s) for cooling. Refrigerant used for cooling must always be subcooled for optimal indoor unit LEV performance; alternate branch devices with no subcooling risk bubbles in liquid supplied to LEV and are not allowed.

#### B. BC Unit Cabinet:

1. The casing shall be fabricated of galvanized steel.
2. Each cabinet shall house multiple refrigeration control valves.

#### C. Refrigerant

1. Low GWP refrigerant shall be required.

#### D. Refrigerant Branches

1. All RC Controller refrigerant pipe connections shall be brazed or flared.

#### E. Refrigerant valves:

1. The unit shall be furnished with multiple branch circuits which can individually accommodate up to 54,000 BTUH and up to eight indoor units as shown in drawings.
2. Each branch shall have valves to control refrigerant flow.
3. Service shut-off valves shall be field-provided/installed for each branch to allow service to any indoor unit without field interruption to overall system operation.
4. Linear electronic expansion valves shall be used to control the variable refrigerant flow.

#### F. Future Use

1. Each system shall include at least one (1) unused branches or branch devices for future use. Branches shall be fully installed & wired in central location with capped service shutoff valve & service port.

#### G. Integral Drain Pan:

1. An Integral resin drain pan and drain shall be provided

#### H. Electrical:

1. The unit electrical power shall be as scheduled on drawings.
2. The RC/BS Controller shall be controlled by integral microprocessors
3. The control circuit between the indoor units and outdoor units shall be 24VDC completed using a 2-conductor, twisted pair shielded cable to provide total integration of the system.

## INDOOR, MOUNTED UNITS FOR DUCTING (non-DOAS))

### A. Cabinet:

1. Material: Galvanized or painted steel.
2. Insulation: Manufacturer's standard internal insulation, complying with ASHRAE 62.1, to provide thermal resistance and prevent condensation.
3. Duct Connections: Extended collar or flange designed for attaching field-installed ductwork.
4. Mounting: Manufacturer-designed provisions for field installation.
5. Internal Access: Removable panels or hinged doors of adequate size for field access to internal components for inspection, cleaning, service, and replacement.

### B. DX Coil Assembly:

1. Coil Casing: Aluminum, galvanized, or stainless steel.
2. Coil Fins: Aluminum, mechanically bonded to tubes, with arrangement required by performance shown on equipment schedules in drawings.
3. Coil Tubes: Copper, of diameter and thickness required by performance.
4. Expansion Valve: Electronic modulating type with linear or proportional characteristics.
5. Unit Internal Tubing: Copper tubing with brazed joints.
6. Unit Internal Tubing Insulation: Manufacturer's standard insulation, of thickness to prevent condensation.
7. Field Piping Connections: Manufacturer's standard.
8. Factory Charge: Dehydrated air or nitrogen.
9. Testing: Factory pressure tested and verified to be without leaks.

### C. Drain Assembly:

1. Pan: Non-ferrous material, with bottom sloped to low point drain connection.
2. Condensate Removal: Unit-mounted pump or other integral lifting mechanism, capable of lifting drain water to an elevation above top of cabinet.
3. Field Piping Connection: Non-ferrous material with threaded NPT.

### D. Fan and Motor Assembly:

1. Fan(s):
  - a. Direct-drive arrangement.
  - b. Single or multiple fans connected to a common motor shaft and driven by a single motor.
  - c. Fabricated from non-ferrous components or ferrous components with corrosion-resistant finish.
  - d. Wheels statically and dynamically balanced.
2. Motor: Brushless dc or electronically commutated with permanently lubricated bearings.
3. Motor Protection: Integral protection against thermal, overload, and voltage fluctuations.
4. Speed Settings and Control: Two (low, high), three (low, medium, high), or more than three speed settings or variable speed with a speed range of least 50 percent.
5. Vibration Control: Integral isolation to dampen vibration transmission.

### E. Filter Assembly:

1. Access: Bottom, side, or rear to accommodate field servicing without removing ductwork and to accommodate filter replacement without need for tools.
  2. Efficiency: ASHRAE 52.2, MERV 13.
  3. Media:
    - a. Replaceable: Extended surface, panel, or cartridge with antimicrobial treatment fiber media.
- F. Unit Accessories:
1. Outdoor Air Ventilation Kit: Connection, motorized damper, and control sized to allow sequence of operation indicated on Drawings.
  2. Remote Room Temperature Sensor Kit: Wall-mounted, hardwired room temperature sensor kit for use in rooms that do not have room temperature measurement.
- G. Unit Controls:
1. Enclosure: suitable for indoor locations as shown on drawings.
  2. Factory-Installed Controller: Configurable digital control.
  3. Factory-Installed Sensors:
    - a. Unit inlet air temperature.
    - b. Coil entering refrigerant temperature.
    - c. Coil leaving refrigerant temperature.
  4. Field-Customizable I/O Capability:
    - a. See MI sheets
  5. Features and Functions:
    - a. Self-diagnostics.
    - b. Time delay.
    - c. Auto-restart.
    - d. External static pressure control.
    - e. Auto operation mode.
    - f. Manual operation mode.
    - g. Filter service notification.
    - h. Power consumption display.
    - i. Drain assembly high water level safety shutdown and notification.
    - j. Run test switch.
  6. Communication: Network communication with other indoor and outdoor units.
  7. Cable and Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
  8. Field Connection: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
- H. Unit Electrical:
1. Enclosure: Metal, suitable for indoor locations as shown on drawings with service clearances as shown.
  2. Field Connection: Single point connection to power unit and integral controls.
  3. Disconnecting Means: Factory-mounted circuit breaker or switch.

4. Control Transformer: Manufacturer's standard. Coordinate requirements with field power supply.
5. Wiring: Manufacturer's standard with each connection labeled and corresponding to a unit-mounted wiring diagram.
6. Raceways: Enclose line voltage wiring in metal raceways.

## **PART 1** INSTALLATION

### 1.1 GENERAL

- A. Install system and materials in accordance with manufacturer's instructions, and as detailed on the project drawing set.
- B. Line and low voltage electrical connections to control equipment shown specified or shown on the control diagrams shall be furnished and installed by the Control System Contractor.
- C. Equipment furnished by the Mechanical Contractor that is normally wired before installation shall be furnished completely wired. Control wiring normally performed in the field will be furnished and installed by the Control System Contractor.
- D. All control devices mounted on the face of control panels shall be clearly identified as to function and system served with permanently engraved phenolic labels.
- E. All controls shall be BACNet compatible.

### 1.2 WIRING

- A. All electrical control wiring to the control panels shall be the responsibility of the Installing Contractor.
- B. All wiring shall be in accordance with the Project Electrical Specifications (Division 16), the National Electrical Code and any applicable local codes. All control wiring shall be installed in raceways.

## **PART 2** PROJECT CLOSEOUT

### 2.1 ACCEPTANCE TESTING

- A. Upon completion of the installation, the Control System Contractor shall load all system software and start-up the system. The Control System Contractor shall perform all necessary calibration, testing and de-bugging and perform all required operational checks to insure that the system is functioning in full accordance with these specifications.
- B. The Control System Contractor shall perform tests to verify proper performance of components, routines, and points. Repeat tests until proper performance results. This testing shall include a point-by-point log to validate 100% of the input and output points of the DDC system operation.
- C. System Acceptance: Satisfactory completion is when the Control System Contractor has performed successfully all the required testing to show performance compliance with the requirements of the Contract Documents to the satisfaction of the Owner's Representative. System acceptance shall be contingent upon completion and review of all corrected deficiencies.

### 2.2 OPERATION & MAINTENANCE MANUALS

- A. See Division 1 for requirements. O&M manuals shall include the following elements, as a minimum:
  1. As-built control drawings for all equipment.
  2. As-built Network Communications Diagram.

3. General description and specifications for all components.
4. Completed Performance Verification sheets.
5. Completed Controller Checkout/Calibration Sheets.

### 2.3 OPERATOR TRAINING

- A. During system commissioning and at such time acceptable performance of the Control System hardware and software has been established, the Control System Contractor shall provide on-site operator instruction to the owner's operating personnel. Operator instruction shall be done during normal working hours and shall be performed by a competent representative familiar with the system hardware, software and accessories.
- B. The Control System Contractor shall provide comprehensive training for system orientation, product maintenance and troubleshooting, programming and engineering
- C. The Control System Contractor shall provide instruction to the owner's designated personnel on the operation of the BMS and describe its intended use with respect to the programmed functions specified. Operator orientation of the BMS shall include, but not be limited to; the overall operation program, equipment functions (both individually and as part of the total integrated system), commands, systems generation, advisories, and appropriate operator intervention required in responding to the System's operation
- D. The VRF manufacturer shall provide the owner's representative a minimum 16-hour VRF Operation and Maintenance training class covering systems installed under this scope of work.
  1. Training program is to be provided at the time of owner occupancy for 8 hours and another 8 hours at 6 months after occupancy.
  2. Owner shall provide a suitable location, onsite, to conduct the VRF Operation and Maintenance class.
  3. Training material shall be provided to participants in electronic format.

**END OF SECTION 23 81 27**