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PRESIDENTIAL PALACE – REPUBLIC OF LEBANON

BAABDA - LEBANON

CHILLER PLANT SYSTEM SPECIFICATIONS

SEPTEMBER 2025

MECHANICAL

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SECTION 010005 - PROJECT OUTLINE AND DESCRIPTION

A. General

This Book of Specifications covers the General and Particular Specifications for the Chiller Plant System of the “PRESIDENTIAL PALACE” project in BAABDA, LEBANON.

B. Project Outline

The project consists of the replacement of the existing water cooled chillers, chilled water pumps, cooling towers and cooling towers pumps with all valves, controls and accessories for the PRESIDENTIAL PALACE .

END OF SECTION 010005

SECTION 010010 - GENERAL CONDITIONS

A. Scope of Work

Works under this Contract shall include, but not be limited to, the supply, installation, testing and delivery in good operating conditions of all systems, equipment, components, etc... as specified under their respective clauses, relevant drawings and the following general stipulations.

Each material (paints, coatings, sealants, adhesives VOCs, Recycled Contents...), equipment (pumps, chillers efficiencies...) to be installed on site, shall meet Sustainability Green Building Requirements, based on ANSI/ASHRAE latest Handbooks/Standards and not limited to the following:

1. ASHRAE Handbook – HVAC Applications
2. ASHRAE Handbook – HVAC Systems & Equipment
3. ASHRAE Handbook – Fundamentals
4. ASHRAE Handbook – Refrigeration
5. ASHRAE/ANSI – Standards:
 - a) 15: Safety Standard for Refrigeration Systems
 - b) 52.2: Filter Rating (MERV)
 - c) 55: Thermal Environmental Conditions for Human occupancy
 - d) 62.1: Ventilation for Acceptable Indoor Air Quality
 - e) 90.1: Energy Standard for Buildings, Except Low-Rise Residential Buildings.
 - f) 90.2: Energy-Efficient Design of Low-Rise Residential Buildings.
 - f) 189.1: Standard for the Design of High-Performance Green Buildings, Except Low-Rise Residential Buildings.

1. Extent of Supply

- a. All necessary components, accessories, manpower, tools, scaffoldings, cutting and patching in walls and slabs, painting, testing, etc..., shall be provided by the Contractor at his own expenses to execute the specified systems complete and in good working conditions.
- b. Accessories and particulars specified with each item are deemed to be minimum requirements and do not limit the Contractor's supply to them.
- c. All accessories and particulars not specifically listed, but necessary to the satisfactory operation and protection of the installation shall be included in the Contractor's supply at no additional cost.
- d. Easily removable and sturdy construction protective guards on all moving equipment or live components.

2. Drawings

- a. Drawings show the general arrangement of equipment and routings of ducts, pipes, cables or conduits. Minor modifications may be allowed to suit Contractor's equipment and site conditions, subject to the approval of the Engineer.

3. Availability of Materials

- a. At the bid stage, the Contractor shall make sure that he can supply all items specified within the time limit set for the project. Any reservations shall be submitted to the Employer before Tender closing date.
- b. Equipment and material not available on the local market, or temporarily out of stock, shall be ordered at an early date after obtaining the Engineer's approval to avoid delays or stoppage of work.
- c. Contractor shall be the sole responsible for resulting delays and the Engineer reserves himself the right to order equipment and material and air freight them, if need be, at Contractor's expenses and responsibility.

4. Submittals

- a. Prior to ordering and/or installation, the Contractor shall submit to the Engineer's approval samples, technical catalogues, performance curves, shop drawings, construction details, calculations, etc..., for equipment, materials and installations specified under this Contract.
- b. The Contractor shall also submit to the Engineer the necessary dimensioned drawings showing all sleeves and openings required by him ahead of time before concrete pouring or execution of masonry structures.
- c. Before taking over the installation, the Contractor shall submit to the Engineer operating and maintenance instructions manuals for the whole works and shall instruct the Engineer or his representative on the method of operation and maintenance of the installed systems.

5. Co-ordination

- a. The Contractor shall take into consideration that the works specified shall be carried out in conjunction with other trades. He shall therefore be responsible to co-ordinate the execution of his works with these other trades and at no additional cost to the Employer.
- b. Prior to ordering or installation of electrical systems, equipment, controls and/or components, the Contractor shall ascertain himself with the local power authority of the electric supply characteristics.
- c. The Contractor shall foresee all openings required in walls, slabs or structural members to reduce to a minimum piercing and breaking works. All works of cutting, patching, piercing, making good, etc..., as well as all excavation and backfilling, cleaning the site of excess material, debris and dirt resulting therefrom, shall be executed by the Contractor and at his own expense.
- d. Whenever cutting and drilling is made on finished surfaces, the Contractor shall make good these surfaces by returning them to their finished original condition and at no additional costs.

A. Equipment and Items Supplied by the Contractor

All equipment and materials supplied by the Contractor shall be brand new, of the latest model and bearing manufacturer's name and corresponding particulars as deemed necessary. Unless specifically mentioned otherwise, all equipment and items specified and/or shown on the drawings shall be transported, installed, connected to Mechanical and Electrical Services, finished and tested in good working and operating conditions by the Contractor.

B. Tender Drawings

The Contractor shall be responsible for the execution of the works in accordance with the Tender Drawings. Modifications to these drawings may be allowed to suit equipment supplied by the Contractor and conform site contingencies, subject to the approval of the Engineer.

All drawings accompanying the Specifications are to be read in conjunction with each other and shall be considered as a whole. Any works indicated on them and not specifically mentioned in the Specifications, and vice-versa, are deemed to be included in the overall Scope of Works.

Tender Drawings are design and not working drawings; they include general layouts of various systems and equipment to be provided and installed.

While every effort has been made to produce comprehensive Tender Drawings, and unless specifically indicated otherwise, these drawings show approximate locations of machines, equipment, pipings, valves, ductworks, cables, feeders, etc... Exact locations shall be determined by the Contractor to comply with selected equipment requirements and space reservations in full co-ordination with other trades and subject to the Engineer's approval

D. Shop Drawings

Before starting works on site or ordering materials and equipment, the Contractor shall submit to the Engineer's approval shop drawings showing the followings:

- a. Equipment and services layout showing clearances and the relation of equipment, piping and cabling to spaces assigned, at a scale not less than 1:50.
- b. Clearances and accesses required for operation and maintenance.
- c. Sizes, capacities, locations and fixing methods of equipment and items supplied.
- d. Equipment weights, bases, fixings, anchoring details, supports, anchor blocks, etc...
- e. Particular details pertaining to special conditions that may be required by the Engineer

Suppliers' approved shop drawings shall be submitted to the Engineer after ordering. Should it be necessary, working drawings shall be revised accordingly.

The Engineer reserves himself the right to approve, modify, alter or reject shop drawings if found incomplete or not complying with the requirements of the Tender Documents.

E. Codes and Standards

Where equipment, materials, methods of erection and testing are specified to conform to certain International Codes and Standards, they shall conform to their latest edition. A copy of the relevant standard shall be submitted with each submittal for approval.

Electric equipment and material supplied under Mechanical Systems shall conform to the recommendations of the International Electro-Technical Commission.

Unless specifically stated otherwise, all Electrical Installation Works shall be tested in compliance with the Regulations for Electrical Equipment of Buildings.

In addition to the above, Works shall conform to the regulations and ordinances of Local Authorities.

Abbreviations are to mean the followings:

ANSI - American National Standards Institute

ASTM - American Society for Testing and Materials

ASME - American society of Mechanical Engineers

BS - British Standards

DIN - Deutsches Institute fur Normalisierung

ISO - International Standardization Organization

FM - Factory Mutual

NBS - National Bureau of Standards

SAE - Society of Automotive Engineers

UL - Underwriters Laboratories Inc.

EN - European Norm

NFPA - National Fire Protection Association

ASHRAE - American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.

CIBSE - Chartered Institute of Building Service Engineers (CIBSE) reference book.

ASPE - American Society of Plumbing Engineers.

F. Equipment Capacities and Particulars

Capacities given in the Specifications, Schedules or shown on the drawings are the minimum acceptable capacities; the Contractor shall select, install or construct all equipment and systems to meet at least these values. All equipment shall be suitable for operation under the severest conditions to be expected for the Project.

No extra payments shall be given to the Contractor as a result of selection, installation or construction of equipment and systems having capacities or sizes in excess to the specified requirements.

All equipment, panels, cables, control gears, circuit breakers, systems, etc... shall be derated to the ambient design conditions stated for the project.

G. Omissions from Tender Documents

The Contractor is required to inform the Employer of possible omissions or apparent discrepancies that may be encountered in the Tender Documents (Book of Specifications and Drawings), which, if approved by the Employer, will form the object of an addendum to the Specifications.

Failure of the Contractor to point out possible omissions or discrepancies shall be considered that he has included the effects of these discrepancies in his pricing, and shall not be entitled to any compensation as a result there from.

H. Interference and Erroneous Locations

The Contractor shall verify on site all data and final locations of work executed under other trades to co-ordinate systems interconnections accordingly.

In case of interference or erroneous locations with respect to structures, equipment, etc... The Contractor shall supply all labour and materials necessary to complete the work in an acceptable manner.

I. Co-ordination of Trades

The Contractor shall foresee in time all openings required in walls, beams, or slabs to reduce a minimum all works of cutting, piercing and making good. He shall be responsible for dimensioning of sleeves, forms, inserts, access doors, etc... Furthermore, if new concrete pouring is to be carried out he shall install all drains, pipes, conduits, boxes and sleeves wherever required and/or shown on the drawings before concrete pouring.

The Contractor shall be in constant contact with the Concretor to inform him of above requirements ahead of time and shall submit to him all relevant drawings and details showing locations and sizes of sleeves and openings.

All cutting and patching works in slabs and walls, all preparatory or complementary works required, as well as all labour and material supply in connection with these works, shall be at the Contractor's expenses who shall not be entitled to any payments or claims as a result thereof no matter how difficult or precise they may come out to be. The Contractor is advised that the works specified herein shall be carried out in conjunction with other trades and he shall be responsible to co-ordinate the execution of his works with them and at no additional cost to the Employer.

J. Hook-Ups

Hook-ups to other systems and equipment shall be provided to ensure the satisfactory performance of the overall project.

K. Protection of Electrical Equipment

Electrical equipment shall not be stored out doors and shall be constantly protected from weather, dripping or splashing water. When installed or stored in moist areas, acceptable means to prevent moisture damage shall be provided.

Should any equipment or material be subjected to possible damage by water, it shall be dried out thoroughly and put through a special dielectric test as directed, at the expenses of the Contractor; if permanently damaged, it shall be replaced at the Contractor's own expenses.

L. Programme of Work

Within four weeks after award of Contract, the Contractor shall submit to the Engineer's approval a detailed programme of work for all phases of the project, showing the proposed dates and periods for material submission for approval, getting approvals, ordering, shipping, preparation of working drawings, equipment arrival on site, start of erection, progress of erection, completion, testing and final taking-over.

Within the same period, the Contractor shall submit lists of equipment and materials, with names of proposed manufacturers, and drawings of inter-related items. Lists and Drawings are to show submission dates.

The Contractor shall allow in his programme for the time needed by the Engineer for approval of materials and shop drawings, which is to be between two to three weeks. No work on site shall be allowed to proceed unless the programme of work is submitted and approved by the Engineer.

M. Submittals

All submittals shall be presented to the Engineer with a covering letter in which the Contractor states the subject and purpose of the submittal.

Each submittal shall conform to the following stipulations:

1. Working Drawings or Shop Drawings & Materials Submittals
 - a. Two months prior to commencement, Contractor shall submit for approval detailed shop drawings (working drawings) showing to-scale dimensions of equipment, pipes, ducts etc. in plan and elevation with clearances and relation of same to space assigned, showing also location, type and spacing of supports to equipment, pipes, ducts, etc.. Scale to be not less than 1/50 for general plans and 1/20 for toilet areas.
 - b. Shop drawings for equipment and materials shall include detailed manufacturer's drawings, detailed catalogues and descriptive literature showing type, performance characteristics, construction, component parts, dimensions, arrangement, operating clearances, capacity, electrical characteristics, power requirements, motor, drive and testing information.
 - c. Indicate, with reasons any deviations from the Specifications and Drawings. No modification to the Contract Documents is authorized unless issued in writing in a change order by the Engineer.
 - d. No equipment or materials shall be purchased or delivered to Site until such equipment; materials have been approved by the Engineer.
 - e. Shop Drawings shall be submitted in triplicate with each submittal.
 - f. Shop Drawings for equipment and material shall be submitted in triplicate with each submittal. At least one copy of catalogues shall be original and not photocopied.
 - g. Refer to other sections for other requirements of Working or Shop Drawings.
2. As-Built Drawings

Contractor shall provide As-Built Drawings and submit them for the Engineer's approval. After approval of as-built drawings, the Contractor shall submit the original plus a reproducible mother print of each drawing. Moreover, two sets of blue prints of each drawing shall be submitted with the originals.
3. Samples

Two samples of each item shall be required with each submittal and three sets of technical literatures or catalogues, with at least one original copy.

N. Consistency of Supplied Items

It is pointed out to the Contractor, that equipment controls, accessories, etc..., falling under the same service, shall be supplied from the same manufacturer unless specifically directed otherwise by the Engineer.

The followings illustrate equipment and accessories considered to be falling under the same services:

- a. Pumps.
- b. Pipes and accessories.
- c. Valves.
- d. Controls.
- e. Insulation.
- f. Cables and wires.
- g. Panel boards.

O. Approved Manufacturers

In specifying and selecting equipment, fixtures or accessories, model numbers of certain manufacturers' catalogues are referred to; this procedure is adopted to describe the type, shape, and/or function of the items specified, and to establish standard of quality and performance. Other items from approved manufacturers, judged by the Engineer to be similar in shape and performance to the one specified, will be accepted. Reference to approved manufacturers and model numbers does not imply approval of same. Contractors shall submit all equipment and materials for approval irrespective of whether a model number or approved manufacturer is listed or not. It is pointed out that the term "or approved equal" shall mean items or equipment approved by the Engineer, whose decision in approving or rejecting shall be final and not subject to any justifications.

P. Samples

Before ordering and starting the works, the Contractor shall submit to the Engineer's approval samples of the various items to be supplied and installed by him.

These shall include namely:

- a. Pipes, pipes fittings and pipes supports.
- b. Valves and specialties items (i.e. safety valves, strainers, air vents, etc.)
- c. Insulation for pipes and equipment.
- d. Meters, gauges and controls.
- e. Cables and wires.

The above illustrate the main types of samples required, and does not limit the supply of these items only. The Engineer reserves to himself the right to request any sample not specifically mentioned above at any stage of work progress.

All samples are deemed to be submitted at the Contractor's own expenses and at no additional charges to the Employer.

Q. Maintenance Prior to Completion Date

The Contractor shall be responsible for the maintenance of all equipment and systems installed by him until final acceptance by the Engineer. He shall therefore take necessary measures to insure adequate protection of all equipment and materials during delivery, storage, installation and shutdown.

This responsibility shall include all provisions required to meet the imperatives incidental to the delays pending final test of systems and equipment under seasonal conditions.

After installation of systems have been completed, the Contractor shall operate them for period of times sufficient to complete all tests, to balance, adjust and demonstrate that performance is in accordance with design.

R. As-Built Drawings

Upon completion of the Works, the Contractor shall submit to the Engineer the original plus a reproducible mother print and two sets of blue prints of the approved as-built drawings showing the final routing, layout and location of equipment, pipes, cables, etc...

These drawings shall be submitted within one month after completion date, and no payment will be affected upon completion unless the drawings have been received by the Engineer.

S. Operation and Maintenance (O & M) Instruction Manuals

The Contractor/subcontractor is responsible to assign a specialist firm (with minimum 10 years of experience in this field) for the preparation of the O & M manuals for the Mechanical services. The specialist firm shall be certified NEBB (National Environmental Balancing Bureau) or AABC (Associated Air Balance Council). The specialist firm shall provide 3 hard and 3 electronic copies the below information but not limited to:

1. Brief description of each system and piece of equipment with basic operating features
2. Descriptive literature of equipment and components with manufacturer's name, model number, capacity rating and operating characteristics
3. Service manual prepared by manufacturer for every major piece of equipment giving operating and maintenance instructions, starting and shutdown instructions, lubrication instructions and list of possible breakdown and repairs
4. Manufacturer's list of general spare parts for every piece of equipment, with unit prices.

The Contractor shall provide for each system, equipment and accessories, three copies in bound booklet form containing the following information:

5. Manufacturer's list of recommended spare parts for one year of operation for every piece of equipment, with unit prices
6. Detailed and simplified one line, colour coded flow diagram of each system with tag number, location and function of each valve and instrument
7. Detailed and simplified colour coded as-installed wiring diagrams of motor controllers and automatic controls with tag number, location of each instrument and electrical device with description of sequence of operation and interlocks.
8. Instruction manuals shall be submitted in draft form for review and approval prior to final issue and at least four weeks in advance of completion date of the system. Completion certificate shall not be issued if the above are not submitted and approved.

T. Access Doors and Frames

The Contractor shall install work to be readily accessible for operation, maintenance and repair. Approved devices from the Drawings may be made to accomplish this.

The Contractor shall ensure that access doors and frames are provided for easy access to concealed equipment, controls, valves, traps, vents, drains, clean-outs, and other devices requiring periodic operation, inspection and maintenance.

Access doors and frames are to be provided by others. Provide details, dimensions and locations of access doors required and submit for approval in sufficient time to enable doors to be installed during normal course of work.

Access doors are to be identified to indicate location of concealed work. Method and schedule for identification of access doors is to be approved.

U. Nameplates, Labels, Tags and Charts

Each piece of equipment is to have a conspicuous certified nameplate permanently attached at factory, printed or stamped clearly with name and address of manufacturer, equipment model number, serial number, date of manufacture, electrical characteristics, performance rating or duty, pressure, temperature or other limitations and other pertinent data.

Equipment, instruments, controls, electrical devices, valves etc. shall be labelled and identified as to duty, service or function. Label controls and electrical devices to indicate clearly what they control.

Labels shall be of laminated Bakelite with black surface and white core with incised lettering nomenclature written in English.

Labels shall be attached to equipment or to adjacent permanent surfaces in an approved permanent manner. Controls and instruments that cannot be easily identified shall be tagged with Bakelite labels.

All valves and controls except equipment shut-off valves located at equipment shall be tagged.

Tags shall consist of 5cm diameter by 1.5mm thick aluminium sheet with stamped numbers and letters filled with black paint.

The Contractor shall submit for approval a schedule of equipment and devices to be labelled and tagged, with suggested nomenclature Charts are to be prepared of schematic flow diagrams of each piping system with location and function of each valve and with type and size of each essential feature of the system, and submitted for approval.

Schedules for equipment lubrication and maintenance and essential operating instructions, shall be prepared in chart form and submitted for approval.

Charts shall be mounted on wooden plaques or 6 mm Masonite boards, cover with heat bonded clear plastic laminate or frame under glass and permanently fix with four brass screws at approved locations.

W. Instruction to Personnel

The Contractor shall be responsible to instruct the personnel team that may be assigned to him by the Employer during execution at no extra charges. Personnel instruction shall include allowing the personnel team to attend installation works, be instructed on the use, operation and maintenance of the various systems, components and equipment.

X. Spare Parts

Spare parts necessary for the normal running of equipment or items during the Guarantee period shall be supplied by the Contractor as part of his responsibilities under this Contract except oils and greases.

Y. Tools

The Contractor shall supply all standard and special tools needed for routine maintenance, adjustment, operation or normal overhaul of equipment supplied by him. Tools shall be brand new, high-grade quality and shall include general purpose spanners, wrenches, screwdrivers, greasing guns, etc. as well as all specialized and customized tools.

Z. Site Facilities

The Contractor shall be responsible to provide for himself all site offices and covered storage facilities he needs in co-ordination with the Engineer.

Stored equipment and items shall be kept clear off the floor and protected from dust and other deteriorating agents.

AA. Works Not Included

The contents of this clause shall not relieve the Contractor's responsibility to co-ordinate his work with other trades to ensure that execution of works not included in his Contract are carried out on time and to his satisfaction. He shall remain responsible for proper functioning of systems connected with other trades for their installation.

- a. Concrete, sump pits and concrete pipe trenches.
- b. Water supply and sewer and rain water outside property limits.
However, the Contractor shall co-ordinate connections to municipal mains with the authorities to obtain permits and authorizations for these connections. He shall pay for expenses related thereto as well as to works to be executed whether carried out by himself or by a Contractor appointed by the authorities.
- c. Close to each equipment control panel, each electrically operated equipment (pumps, etc.), and motor control centers supplied under Mechanical Works, an adequate power supply outlet will be provided by the Electrical Contractor. Final extensions and connections between these outlets and the corresponding panel and/or equipment, as well as all associated controls, wirings, etc... are included in the Mechanical Works.

AB. Co-ordination with Civil Works

Before pouring, the Contractor shall prepare a template to the exact dimensions of equipment anchor bolts, which shall be rigidly secured on the template to the desired depths. When only openings for anchor bolts are required, the templates shall be made with wood strips rigidly secured on it at the bolts locations.

AC. The HVAC system conditions are based on the following design criteria according to the Client's input for MORONI - COMOROS:**a. Outdoor Design Conditions:**

- Summer : 36.0 °C Dry Bulb
 29.0 °C Wet Bulb
- Winter : 5.6 °C Dry Bulb

- b. Electric Power: 3 phases, 4 wires, 50 Hz, 380 volts
 between phases.
 230 volts between phases and neutral
 with solidly earthed neutral.

All equipment, cables, control gears and systems shall be derated to conform to the above-mentioned conditions.

AD. Noise and Vibration

All equipment shall operate under all conditions of load without sound or vibration, which in the opinion of the Engineer is objectionable, and above the criteria limits set here below.

The noise level resulting from equipment ducts, air outlets, etc. and heard in the conditioned spaces shall not result in a noise level in such spaces exceeding 25 decibels as measured with a standard sound level meter on the "A" scale. Noise levels in all occupied spaces shall meet the requirements of International Standards and the acousystem Engineer.

Contractor shall be responsible for achieving the above noise limits and he shall provide all necessary noise attenuation features and accessories such as sound absorbers for equipment, pipes, etc. Whether or not they are indicated on Drawings or specified. Vibration control shall be provided. Equipment shall not result in any vibration transmitted to the building. Provide vibration isolators, inertia blocks etc. to achieve the above.

AE. Guarantee

The Contractor shall guarantee all his works for a period of **two years** beginning after the issuing of the Completion Certificate of all the works specified herein. The guarantee shall cover all works, manpower, spare parts, replacements, etc. resulting from failure of equipment, systems and accessories supplied by the Contractor. Guarantee shall apply also for perfect mechanical operation of the system and equipment, acceptable noise and vibration levels and reasonable consumption of power, fuel and water.

If during the guarantee period any equipment or material proves defective or any part of system fails to function properly, equipment is to be replaced and defects and malfunctions corrected as directed by the Engineer.

If during the guarantee period any piece of equipment is replaced or rebuilt, the guarantee period for this is to be extended for a new period equal to the original guarantee period.

Contractor shall provide necessary skills and labour to assure proper operation and to provide regular and preventive maintenance required for equipment and controls during the guarantee period, on a continuous 24-hour basis.

The contractor shall act promptly to correct problems arising in operation of equipment or system.

The contractor shall provide the Employer with monthly inspection certificates of equipment, record findings on a check list and certify that each piece of equipment has been examined, is operating as intended and has been properly maintained as recommended by the manufacturer.

The contractor shall check all controls monthly to ascertain that they function as designed.

Spare parts for normal wear and tear are to be provided by the Employer.

END OF SECTION 010010

SECTION 230519 - METERS AND GAUGES FOR HVAC 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. Bimetallic-actuated thermometers.
2. Filled-system thermometers.
3. Liquid-in-glass thermometers.
4. Light-activated thermometers.
5. Duct-thermometer mounting brackets.
6. Thermowells.
7. Dial-type pressure gages.
8. Gage attachments.
9. Test plugs.
10. Test-plug kits.
11. Sight flow indicators.
12. Flowmeters.
13. Thermal-energy meters.

B. Related Requirements:

1. Section 231123 "Facility Natural-Gas Piping" for gas meters.
2. Section 232216 "Steam and Condensate Piping Specialties" for steam and condensate meters.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Shop Drawings:

1. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Product Certificates: For each type of meter and gage.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For meters and gages to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 BIMETALLIC-ACTUATED THERMOMETERS

- A. Standard: ASME B40.200.
- B. Case: [**Liquid-filled**] [**and**] [**sealed**] type(s); stainless steel with [**3-inch (76-mm)**] [**5-inch (127-mm)**] nominal diameter.
- C. Dial: [**Nonreflective aluminum**] with permanently etched scale markings and scales in [**deg F (deg C)**].
- D. Connector Type(s): Union joint, [**adjustable angle**] [**rigid, back**] [**and**] [**rigid, bottom**] , with unified-inch screw threads.
- E. Connector Size: [**1/2 inch (13 mm)**] , with ASME B1.1 screw threads.
- F. Stem: **0.25 or 0.375 inch (6.4 or 9.4 mm)** in diameter; stainless steel.
- G. Window: [**Plain glass**] .
- H. Ring: Stainless steel.
- I. Element: Bimetal coil.
- J. Pointer: Dark-colored metal.
- K. Accuracy: Plus or minus [**1**] percent of scale range.

2.2 FILLED-SYSTEM THERMOMETERS

- A. Direct-Mounted, Metal-Case, Vapor-Actuated Thermometers:
 - 1. Standard: ASME B40.200.
 - 2. Case: Sealed type, [**cast aluminum or drawn steel**] ; [**6-inch (152-mm)**] nominal diameter.
 - 3. Element: Bourdon tube or other type of pressure element.
 - 4. Movement: Mechanical, [**dampening type,**] with link to pressure element and connection to pointer.
 - 5. Dial: Nonreflective aluminum with permanently etched scale markings graduated in [**deg F (deg C)**].
 - 6. Pointer: Dark-colored metal.
 - 7. Window: [**Glass**] .
 - 8. Ring: [**Metal**] [**Stainless steel**] .

9. Connector Type(s): Union joint, [**adjustable, 180 degrees in vertical plane, 360 degrees in horizontal plane, with locking device**] [**rigid, back**] [**and**] [**rigid, bottom**]; with ASME B1.1 screw threads.
10. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
11. Accuracy: Plus or minus [**1**] percent of scale range.

B. Remote-Mounted, Metal-Case, Vapor-Actuated Thermometers:

1. Standard: ASME B40.200.
2. Case: Sealed type, [**cast aluminum or drawn steel**] [**6-inch (152-mm)**] nominal diameter with [**back**] [**front**] flange and holes for panel mounting.
3. Element: Bourdon tube or other type of pressure element.
4. Movement: Mechanical, with link to pressure element and connection to pointer.
5. Dial: Nonreflective aluminum with permanently etched scale markings graduated in [**deg F (deg C)**].
6. Pointer: Dark-colored metal.
7. Window: [**Glass**] .
8. Ring: [**Metal**] [**Stainless steel**] .
9. Connector Type(s): Union joint, [**back**] [**bottom**]; with ASME B1.1 screw threads.
10. Thermal System: Liquid-filled bulb in copper-plated steel, aluminum, or brass stem and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
11. Accuracy: Plus or minus [**1**] percent of scale range.

2.3 LIQUID-IN-GLASS THERMOMETERS

A. Metal-Case, Compact-Style, Liquid-in-Glass Thermometers:

1. Standard: ASME B40.200.
2. Case: [**Cast aluminum**] ; [**6-inch (152-mm)**] nominal size.
3. Case Form: [**Back angle**] [**Straight**] unless otherwise indicated.
4. Tube: Glass with magnifying lens and blue[**or red**] organic liquid.
5. Tube Background: Nonreflective aluminum with permanently etched scale markings graduated in [**deg F (deg C)**] .
6. Window: Glass or plastic.
7. Stem: Aluminum or brass and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
8. Connector: **3/4 inch (19 mm)**, with ASME B1.1 screw threads.
9. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

2.4 LIGHT-ACTIVATED THERMOMETERS

A. Direct-Mounted, Light-Activated Thermometers:

1. Case: **[Metal]**; **[7-inch (178-mm)]** nominal size unless otherwise indicated.
2. Scale(s): **[Deg F (Deg C)]**.
3. Case Form: **[Adjustable angle]**.
4. Connector: **[1-1/4 inches (32 mm)]** <>, with ASME B1.1 screw threads.
5. Stem: **[Aluminum]** and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
6. Display: Digital.
7. Accuracy: Plus or minus **2 deg F (1 deg C)**.

B. Remote-Mounted, Light-Activated Thermometers:

1. Case: Plastic, for wall mounting.
2. Scale(s): **[Deg F (Deg C)]**.
3. Sensor: Bulb and thermister wire.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
4. Display: Digital.
5. Accuracy: Plus or minus **2 deg F (1 deg C)**.

2.5 DUCT-THERMOMETER MOUNTING BRACKETS

- ### A. Description: Flanged bracket with screw holes, for attachment to air duct and made to hold thermometer stem.

2.6 THERMOWELLS

A. Thermowells:

1. Standard: ASME B40.200.
2. Description: Pressure-tight, socket-type fitting made for insertion in piping tee fitting.
3. Material for Use with Copper Tubing: **[CNR]** **[or]** **[CUNI]**.
4. Material for Use with Steel Piping: **[CRES]** **[CSA]**.
5. Type: Stepped shank unless straight or tapered shank is indicated.
6. External Threads: **NPS 1/2, NPS 3/4, or NPS 1, (DN 15, DN 20, or NPS 25,)** ASME B1.20.1 pipe threads.
7. Internal Threads: **1/2, 3/4, and 1 inch (13, 19, and 25 mm)**, with ASME B1.1 screw threads.
8. Bore: Diameter required to match thermometer bulb or stem.
9. Insertion Length: Length required to match thermometer bulb or stem.
10. Lagging Extension: Include on thermowells for insulated piping and tubing.
11. Bushings: For converting size of thermowell's internal screw thread to size of thermometer connection.

- B. Heat-Transfer Medium: **[Mixture of graphite and glycerin]** .

2.7 DIAL-TYPE PRESSURE GAGES

- A. Direct-Mounted, Metal-Case, Dial-Type Pressure Gages:
1. Standard: ASME B40.100.
 2. Case: **[Liquid-filled]** **[Sealed]** type(s); **[cast aluminum or drawn steel]**; **[6-inch (152-mm)]** nominal diameter.
 3. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
 4. Pressure Connection: Brass, with **[NPS 1/4 or NPS 1/2 (DN 8 or DN 15)]**, ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
 5. Movement: Mechanical, with link to pressure element and connection to pointer.
 6. Dial: Nonreflective aluminum with permanently etched scale markings graduated in **[psi (kPa)]**.
 7. Pointer: Dark-colored metal.
 8. Window: **[Glass]** .
 9. Ring: **[Metal]** **[Brass]**.
 10. Accuracy: **[Grade A, plus or minus 1 percent of middle half of]** scale range.
- B. Remote-Mounted, Metal-Case, Dial-Type Pressure Gages:
1. Standard: ASME B40.100.
 2. Case: **[Liquid-filled]** **[Sealed]** type; **[cast aluminum or drawn steel]** **[metal]**; **[6-inch (152-mm)]** nominal diameter with **[back]** **[front]** flange and holes for panel mounting.
 3. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
 4. Pressure Connection: Brass, with **[NPS 1/4 or NPS 1/2 (DN 8 or DN 15)]**, ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
 5. Movement: Mechanical, with link to pressure element and connection to pointer.
 6. Dial: Nonreflective aluminum with permanently etched scale markings graduated in **[psi (kPa)]**.
 7. Pointer: Dark-colored metal.
 8. Window: **[Glass]** .
 9. Ring: **[Metal]** **[Stainless steel]** .
 10. Accuracy: **[Grade A, plus or minus 1 percent of middle half of]** scale range.

2.8 GAGE ATTACHMENTS

- A. Snubbers: ASME B40.100, brass; with **[NPS 1/4 or NPS 1/2 (DN 8 or DN 15)]**, ASME B1.20.1 pipe threads and **[piston]** **[porous-metal]**-type surge-dampening device. Include extension for use on insulated piping.
- B. Siphons: Loop-shaped section of **[brass]** **[stainless-steel]** pipe with **[NPS 1/4 or NPS 1/2 (DN 8 or DN 15)]** pipe threads.
- C. Valves: **[Brass or stainless-steel needle]**, with **[NPS 1/4 or NPS 1/2 (DN 8 or DN 15)]**, ASME B1.20.1 pipe threads.

2.9 TEST PLUGS

- A. Description: Test-station fitting made for insertion in piping tee fitting.
- B. Body: Brass or stainless steel with core inserts and gasketed and threaded cap. Include extended stem on units to be installed in insulated piping.
- C. Thread Size: **[NPS 1/4 (DN 8)] [or] [NPS 1/2 (DN 15)]**, ASME B1.20.1 pipe thread.
- D. Minimum Pressure and Temperature Rating: **[500 psig at 200 deg F (3450 kPa at 93 deg C)]**.
- E. Core Inserts: **[Chlorosulfonated polyethylene synthetic] [and] [EPDM]** self-sealing rubber.

2.10 TEST-PLUG KITS

- A. Furnish **[one]** test-plug kit(s) containing **[one]** thermometer(s), one pressure gage and adapter, and carrying case. Thermometer sensing elements, pressure gage, and adapter probes shall be of diameter to fit test plugs and of length to project into piping.
- B. Low-Range Thermometer: Small, bimetallic insertion type with **[1- to 2-inch- (25- to 51-mm-)]** **<Insert dimension>** diameter dial and tapered-end sensing element. Dial range shall be at least **[25 to 125 deg F (minus 4 to plus 52 deg C)]**.
- C. Pressure Gage: Small, Bourdon-tube insertion type with **[2- to 3-inch- (51- to 76-mm-)]** diameter dial and probe. Dial range shall be at least **[0 to 200 psig (0 to 1380 kPa)]**.
- D. Carrying Case: Metal or plastic, with formed instrument padding.

2.11 SIGHT FLOW INDICATORS

- A. Description: Piping inline-installation device for visual verification of flow.
- B. Construction: Bronze or stainless-steel body, with sight glass and **[ball, flapper, or paddle wheel]** indicator, and threaded or flanged ends.
- C. Minimum Pressure Rating: **[150 psig (1034 kPa)]**.
- D. Minimum Temperature Rating: **[200 deg F (93 deg C)]** .
- E. End Connections for **NPS 2 (DN 50)** and Smaller: Threaded.
- F. End Connections for **NPS 2-1/2 (DN 65)** and Larger: Flanged.

2.12 FLOWMETERS

- A. Turbine Flowmeters:
 - 1. Description: Flowmeter with sensor and indicator.
 - 2. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.

3. Sensor: Impeller turbine; for inserting in pipe fitting or for installing in piping and measuring flow directly in **gallons per minute (liters per second)**.
 - a. Design: Device or pipe fitting with inline turbine and integral direct-reading scale for **[gas] [oil] [water]**
 - b. Construction: Bronze or stainless-steel body, with plastic turbine or impeller.
 - c. Minimum Pressure Rating: **[150 psig (1035 kPa)]**.
 - d. Minimum Temperature Rating: **[180 deg F (82 deg C)]**.
4. Indicator: Hand-held meter; either an integral part of sensor or a separate meter.
5. Accuracy: Plus or minus **[1-1/2]** percent.
6. Display: Shows rate of flow[, **with register to indicate total volume in gallons (liters)**].
7. Operating Instructions: Include complete instructions with each flowmeter.

2.13 THERMAL-ENERGY METERS

A. Ultrasonic, Thermal-Energy Meters:

1. Description: Meter with flow sensor, temperature sensors, transmitter, indicator, and connecting wiring.
2. Flow Sensor: Transit-time ultrasonic type with transmitter.
3. Temperature Sensors: Insertion-type or strap-on transducer.
4. Indicator: Solid-state, integrating-type meter[**with integral battery pack**].
 - a. Data Output: Six-digit electromechanical counter with readout in kilowatts per hour or **British thermal units (joules)**.
 - b. Battery Pack: Five-year lithium battery.
5. Accuracy: Plus or minus **[1]** percent.
6. Display: Visually indicates total fluid volume in **gallons (liters)** and thermal-energy flow in kilowatts per hour or **British thermal units (joules)**.
7. Operating Instructions: Include complete instructions with each thermal-energy meter system.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install thermowells with socket extending **[a minimum of 2 inches (51 mm) into fluid]** and in vertical position in piping tees.
- B. Install thermowells of sizes required to match thermometer connectors. Include bushings if required to match sizes.
- C. Install thermowells with extension on insulated piping.
- D. Fill thermowells with heat-transfer medium.
- E. Install direct-mounted thermometers in thermowells and adjust vertical and tilted positions.

- F. Install remote-mounted thermometer bulbs in thermowells and install cases on panels; connect cases with tubing and support tubing to prevent kinks. Use minimum tubing length.
- G. Install duct-thermometer mounting brackets in walls of ducts. Attach to duct with screws.
- H. Install direct-mounted pressure gages in piping tees with pressure gage located on pipe at the most readable position.
- I. Install remote-mounted pressure gages on panel.
- J. Install valve and snubber in piping for each pressure gage for fluids (except steam).
- K. Install valve and syphon fitting in piping for each pressure gage for steam.
- L. Install test plugs in piping tees.
- M. Install flow indicators in piping systems in accessible positions for easy viewing.
- N. Assemble and install connections, tubing, and accessories between flow-measuring elements and flowmeters according to manufacturer's written instructions.
- O. Install flowmeter elements in accessible positions in piping systems.
- P. Install wafer-orifice flowmeter elements between pipe flanges.
- Q. Install differential-pressure-type flowmeter elements, with at least minimum straight lengths of pipe, upstream and downstream from element according to manufacturer's written instructions.
- R. Install permanent indicators on walls or brackets in accessible and readable positions.
- S. Install connection fittings in accessible locations for attachment to portable indicators.
- T. Mount thermal-energy meters on wall if accessible; if not, provide brackets to support meters.
- U. Install thermometers in the following locations:
 - 1. Inlet and outlet of each hydronic zone.
 - 2. Inlet and outlet of each hydronic boiler.
 - 3. Two inlets and two outlets of each chiller.
 - 4. Inlet and outlet of each hydronic coil in air-handling units.
 - 5. Two inlets and two outlets of each hydronic heat exchanger.
 - 6. Inlet and outlet of each thermal-storage tank.
 - 7. Outside-, return-, supply-, and mixed-air ducts.
- V. Install pressure gages in the following locations:
 - 1. Discharge of each pressure-reducing valve.
 - 2. Inlet and outlet of each chiller chilled-water and condenser-water connection.
 - 3. Suction and discharge of each pump.

3.2 CONNECTIONS

- A. Install meters and gages adjacent to machines and equipment to allow space for service and maintenance of meters, gages, machines, and equipment.
- B. Connect flowmeter-system elements to meters.
- C. Connect flowmeter transmitters to meters.
- D. Connect thermal-energy meter transmitters to meters.

3.3 ADJUSTING

- A. After installation, calibrate meters according to manufacturer's written instructions.
- B. Adjust faces of meters and gages to proper angle for best visibility.

3.4 THERMOMETER SCHEDULE

- A. Thermometers at inlet and outlet of each hydronic zone shall be[**one of**] the following:
 - 1. [Liquid-filled] [Sealed], bimetallic-actuated type.
 - 2. [Direct] [Remote]-mounted, [metal] case, vapor-actuated type.
 - 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.
- B. Thermometers at inlet and outlet of each hydronic boiler shall be[**one of**] the following:
 - 1. [Liquid-filled] [Sealed], bimetallic-actuated type.
 - 2. [Direct] [Remote]-mounted, [metal] -case, vapor-actuated type.
 - 3. [
 - 4. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.
- C. Thermometers at inlets and outlets of each chiller shall be[**one of**] the following:
 - 1. [Liquid-filled] [Sealed], bimetallic-actuated type.
 - 2. [Direct] [Remote]-mounted, [metal] -case, vapor-actuated type.
 - 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.
- D. Thermometers at inlet and outlet of each hydronic coil in air-handling units and built-up central systems shall be[**one of**] the following:
 - 1. [Liquid-filled] [Sealed], bimetallic-actuated type.
 - 2. [Direct] [Remote]-mounted, [metal] -case, vapor-actuated type.
 - 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.

- E. Thermometers at inlets and outlets of each hydronic heat exchanger shall be[**one of**] the following:
1. [Liquid-filled] [Sealed], bimetallic-actuated type.
 2. [Direct] [Remote]-mounted, [metal] -case, vapor-actuated type.
 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.
- F. Thermometers at inlet and outlet of each hydronic heat-recovery unit shall be[**one of**] the following:
1. [Liquid-filled] [Sealed], bimetallic-actuated type.
 2. [Direct] [Remote]-mounted, [metal] -case, vapor-actuated type.
 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.
- G. Thermometers at inlet and outlet of each thermal-storage tank shall be[**one of**] the following:
1. [Liquid-filled] [Sealed], bimetallic-actuated type.
 2. [Direct] [Remote]-mounted, [metal] []-case, vapor-actuated type.
 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.
- H. Thermometers at outside-, return-, supply-, and mixed-air ducts shall be[**one of**] the following:
1. [Liquid-filled] [Sealed], bimetallic-actuated type.
 2. [Direct] [Remote]-mounted, [metal] -case, vapor-actuated type.
- I. Thermometer stems shall be of length to match thermowell insertion length.

3.5 THERMOMETER SCALE-RANGE SCHEDULE

- A. Scale Range for Chilled-Water Piping: [**Minus 40 to plus 160 deg F** (**Minus 40 to plus 100 deg C**)].
- B. Scale Range for Condenser-Water Piping: [**0 to 100 deg F** (**Minus 20 to plus 50 deg C**)].
- C. Scale Range for Heating, Hot-Water Piping: [**0 to 250 deg F** (**0 to 150 deg C**)].
- D. Scale Range for Heating, Hot-Water Piping: [**20 to 240 deg F** (**0 to 150 deg C**)].
- E. Scale Range for Steam and Steam-Condensate Piping: [**0 to 250 deg F** (**0 to 150 deg C**)].
- F. Scale Range for Air Ducts: [**Minus 40 to plus 110 deg F** (**Minus 40 to plus 45 deg C**)].

3.6 PRESSURE-GAGE SCHEDULE

- A. Pressure gages at discharge of each pressure-reducing valve shall be[**one of**] the following:
1. [Liquid-filled] [Sealed] , [direct] [remote]-mounted, metal case.
 2. [Sealed] , [direct] [remote]-mounted, plastic case.
 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.
- B. Pressure gages at inlet and outlet of each chiller chilled-water and condenser-water connection shall be[**one of**] the following:
1. [Liquid-filled] [Sealed], [direct] [remote]-mounted, metal case.
 2. [Sealed] , [direct] [remote]-mounted, plastic case.
 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.
- C. Pressure gages at suction and discharge of each pump shall be[**one of**] the following:
1. [Liquid-filled] [Sealed], [direct] [remote]-mounted, metal case.
 2. [Sealed] , [direct] [remote]-mounted, plastic case.
 3. Test plug with [chlorosulfonated polyethylene synthetic] [EPDM] self-sealing rubber inserts.

3.7 PRESSURE-GAGE SCALE-RANGE SCHEDULE

- A. Scale Range for Chilled-Water Piping: [30-in. Hg to 15 psi (minus 100 to 0 kPa)].
- B. Scale Range for Condenser-Water Piping: [30-in. Hg to 15 psi (minus 100 to 0 kPa)].
- C. Scale Range for Heating, Hot-Water Piping: [30-in. Hg to 15 psi (minus 100 to 0 kPa)].
- D. Scale Range for Steam Piping: [30-in. Hg to 15 psi (minus 100 to 0 kPa)].

3.8 FLOWMETER SCHEDULE

- A. Flowmeters for Chilled-Water Piping: [[Turbine] type.
- B. Flowmeters for Condenser-Water Piping: [[Turbine] type.
- C. Flowmeters for Heating, Hot-Water Piping: [Turbine] type.
- D. Flowmeters for Steam and Steam-Condensate Piping: [Turbine] type.

3.9 THERMAL-ENERGY METER SCHEDULE

- A. Thermal-Energy Meters for Chilled-Water Piping: [**Ultrasonic**] type.
- B. Thermal-Energy Meters for Condenser-Water Piping: [**Ultrasonic**] type.
- C. Thermal-Energy Meters for Heating, Hot-Water Piping: [**Ultrasonic**] type.
- D. Thermal-Energy Meters for Steam and Steam-Condensate Piping: [**Ultrasonic**] type.

END OF SECTION 230519

SECTION 230523.13 - BUTTERFLY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Iron, single-flange (lug-type) butterfly valves.
2. Iron, flangeless (wafer-type) butterfly valves.
3. Ductile-iron, grooved-end butterfly valves.
4. High-performance butterfly valves.
5. Chainwheels.

1.2 DEFINITIONS

- A. CWP: Cold working pressure.
- B. EPDM: Ethylene propylene copolymer rubber.
- C. NBR: ABS, Buna-N, or nitrile butadiene rubber.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of valve.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:

1. Protect internal parts against rust and corrosion.
2. Protect threads, flange faces, grooves, and weld ends.
3. Set butterfly valves closed or slightly open.

B. Use the following precautions during storage:

1. Maintain valve end protection.
2. Store valves indoors and maintain at higher-than-ambient-dew-point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.

- C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

PART 2 - PRODUCTS

2.1 SOURCE LIMITATIONS

- A. Obtain each type of valve from single source from single manufacturer.

2.2 PERFORMANCE REQUIREMENTS

- A. ASME Compliance:

- 1. ASME B16.1 for flanges on iron valves.
 - 2. ASME B16.5 for flanges on steel valves.
 - 3. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 4. ASME B31.1 for power piping valves.
 - 5. ASME B31.9 for building services valves.

- B. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.

- C. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.

- D. Valve Sizes: Same as upstream piping unless otherwise indicated.

- E. Valve Actuator Types:

- 1. Gear Actuator: For valves **NPS 8 (DN 200)** and larger.
 - 2. Hand Lever: For valves **NPS 6 (DN 150)** and smaller.
 - 3. Chainwheel: Device for attachment to gear, stem, or other actuator of size and with chain for mounting height, according to "Installation of Valves" Article.

- F. Valves in Insulated Piping: Provide with **2-inch (50-mm)** extended neck stems.

2.3 IRON, SINGLE-FLANGE (LUG-TYPE) BUTTERFLY VALVES

- A. Iron, Single-Flange (Lug-Type) Butterfly Valves with Stainless Steel Disc:

- 1. Standard: MSS SP-67, Type I.
 - 2. CWP Rating: **[200 psig (1380 kPa)]**.
 - 3. Body Design: Single flange (lug type), suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
 - 4. Body Material: ASTM A126, cast iron or ASTM A536, ductile iron.
 - 5. Seat: **[EPDM] [NBR]**.
 - 6. Stem: One- or two-piece stainless steel.
 - 7. Disc: Stainless steel.

2.4 IRON, FLANGELESS (WAFER-TYPE) BUTTERFLY VALVES

- A. Iron, Flangeless (Wafer-Type) Butterfly Valves with Stainless Steel Disc:
1. Standard: MSS SP-67, Type I.
 2. CWP Rating: **[200 psig (1380 kPa)]**.
 3. Body Design: Flangeless (wafer type), suitable for bidirectional dead-end service at rated pressure.
 4. Body Material: ASTM A126, cast iron or ASTM A536, ductile iron.
 5. Seat: **[EPDM] [NBR]**.
 6. Stem: One- or two-piece stainless steel.
 7. Disc: Stainless steel.

2.5 DUCTILE-IRON, GROOVED-END BUTTERFLY VALVES

- A. Ductile-Iron, Grooved-End Butterfly Valves, 300 CWP:
1. Standard: MSS SP-67, Type I.
 2. **NPS 8 (DN 50)** and Smaller CWP Rating: **300 psig (2070 kPa)**.
 3. **NPS 10 (DN 250)** and Larger CWP Rating: **200 psig (1380 kPa)**.
 4. Body Material: Coated, ductile iron.
 5. Stem: Two-piece stainless steel.
 6. Disc: Coated, ductile iron.
 7. Seal: EPDM.

2.6 HIGH-PERFORMANCE BUTTERFLY VALVES

- A. Single-Flange (Lug-Type) High-Performance Butterfly Valves, Class 300:
1. Standard: MSS SP-68.
 2. CWP Rating: **720 psig (4965 kPa)** at **100 deg F (38 deg C)**.
 3. Body Design: Single flange (lug type), suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
 4. Body Material: **[Carbon] [or] [stainless]** steel.
 5. Seat: Reinforced PTFE or metal.
 6. Stem: Stainless steel; offset from seat plane.
 7. Disc: Type 316 stainless steel.
 8. Service: Bidirectional.

2.7 CHAINWHEELS

- A. Description: Valve actuation assembly with sprocket rim, chain guides, chain[, **and attachment brackets for mounting chainwheels directly to hand wheels**].
1. Sprocket Rim with Chain Guides: **[Ductile or cast iron] [Bronze]**, of type and size required for valve.**[Include zinc or epoxy coating.]**
 2. Chain: **[Hot-dip, galvanized steel] [Brass] [Stainless steel]**, of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine mating flange faces for damage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- D. Do not attempt to repair defective valves; replace with new valves. Remove defective valves from site.

3.2 INSTALLATION OF VALVES

- A. Install valves with unions or flanges at each piece of equipment arranged to allow space for service, maintenance, and equipment removal without system shutdown.
- B. Provide support of piping adjacent to valves such that no force is imposed upon valves.
- C. Locate valves for easy access.
- D. Install valves in horizontal piping with stem at or above center of pipe.
- E. Install valves in position to allow full valve actuation movement.
- F. Install chainwheels on manual actuators for butterfly valves [NPS 4 (DN 100)] and larger and more than [96 inches (2400 mm)] above floor. Extend chains to [60 inches (1520 mm)] above finished floor.
- G. Valve Tags: Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

3.3 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service, but before final adjusting and balancing. If leakage cannot be repaired, replace valve.

3.4 CHILLED-WATER VALVE SCHEDULE

A. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): [Stainless steel] disc, 200 CWP, and [EPDM] [NBR] seat.
2. Iron, Single-Flange Butterfly Valves, NPS 14 to NPS 24 (DN 350 to DN 600): [Stainless steel] disc, 150 CWP, and [EPDM] [NBR] seat.
3. Ductile-Iron, Grooved-End Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): [300] CWP.
4. High-Performance Butterfly Valves: Single flange, carbon-steel body, and [Class 300].

3.5 HEATING-WATER VALVE SCHEDULE

A. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): [Stainless steel] disc, 200 CWP, and [EPDM] [NBR] seat.
2. Iron, Single-Flange Butterfly Valves, NPS 14 to NPS 24 (DN 350 to DN 600): [Stainless steel] disc, 150 CWP, and [EPDM] [NBR] seat.
3. Ductile-Iron, Grooved-End Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): [300] CWP.
4. High-Performance Butterfly Valves: Single flange, carbon-steel body, and [Class 300].

3.6 HIGH-PRESSURE STEAM VALVE SCHEDULE - MORE THAN 15 PSIG (104 kPa)

A. Pipe NPS 2-1/2 (DN 65) and Larger: High-performance butterfly valves, single flange (lug type), carbon-steel body, and [Class 300].

3.7 HIGH-PRESSURE CLEAN STEAM VALVE SCHEDULE - MORE THAN 15 PSIG (104 kPa)

A. Pipe NPS 2-1/2 (DN 65) and Larger: High-performance butterfly valves, single flange (lug type), [stainless steel] body, and [Class 300].

3.8 STEAM-CONDENSATE VALVE SCHEDULE

A. Pipe NPS 2-1/2 (DN 65) and Larger: High-performance butterfly valves, single flange (lug type), carbon-steel body, and [Class 300].

3.9 CLEAN-STEAM-CONDENSATE VALVE SCHEDULE

A. Pipe NPS 2-1/2 (DN 65) and Larger: High-performance butterfly valves, single flange (lug type), [stainless steel] body, and [Class 300].

END OF SECTION 230523.13

SECTION 230523.14 - CHECK VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Bronze swing check valves.
 - 2. Iron swing check valves.
 - 3. Iron, grooved-end swing check valves.

1.2 DEFINITIONS

- A. CWP: Cold working pressure.
- B. EPDM: Ethylene-propylene-diene monomer.
- C. NBR: Nitrile butadiene rubber (also known as "Buna-N").
- D. SWP: Steam working pressure.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of valve.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 - 1. Protect internal parts against rust and corrosion.
 - 2. Protect threads, flange faces, grooves, press connections, and weld ends.
 - 3. Block check valves in either closed or open position.
- B. Use the following precautions during storage:
 - 1. Maintain valve end protection.
 - 2. Store valves indoors and maintain at higher than ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
- C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use stems or other components as lifting or rigging points unless specifically indicated for this purpose in manufacturer's written instructions.

PART 2 - PRODUCTS

2.1 SOURCE LIMITATIONS

- A. Obtain each type of valve from single source from single manufacturer.

2.2 PERFORMANCE REQUIREMENTS

- A. ASME Compliance:
 - 1. ASME B1.20.1 for threads for threaded-end valves.
 - 2. ASME B16.1 for flanges on iron valves.
 - 3. ASME B16.5 for flanges for metric standard piping.
 - 4. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 5. ASME B16.18 for cast copper solder joint.
 - 6. ASME B16.22 for wrought copper solder joint.
 - 7. ASME B16.51 for press joint.
 - 8. ASME B31.1 for power piping valves.
 - 9. ASME B31.9 for building services piping valves.
- B. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.
- C. Provide bronze valves made with dezincification-resistant materials. Bronze valves made with copper alloy (brass) containing more than 15 percent zinc are unacceptable.
- D. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- E. Valve Sizes: Same as upstream piping unless otherwise indicated.
- F. Valve Bypass and Drain Connections: MSS SP-45.

2.3 BRONZE SWING CHECK VALVES

- A. Bronze Swing Check Valves with Bronze Disc, Class 150:
 - 1. Description:
 - a. Standard: MSS SP-80, Type 3.
 - b. CWP Rating: 300 psig (2070 kPa).
 - c. Body Design: Horizontal flow.
 - d. Body Material: ASTM B62, bronze.
 - e. Ends: Threaded.
 - f. Disc: Bronze.

2.4 IRON SWING CHECK VALVES

A. Iron Swing Check Valves with Metal Seats, Class 250:

1. Description:

- a. Standard: MSS SP-71, Type I.
- b. NPS 2-1/2 to NPS 12 (DN 65 to DN 300), CWP Rating: 500 psig (3450 kPa).
- c. NPS 14 to NPS 24 (DN 350 to DN 600), CWP Rating: 300 psig (2070 kPa).
- d. Body Design: Clear or full waterway.
- e. Body Material: ASTM A126, gray iron with bolted bonnet.
- f. Ends: Flanged.
- g. Trim: Bronze.
- h. Gasket: Asbestos free.

2.5 IRON, GROOVED-END SWING CHECK VALVES

A. Iron, Grooved-End Swing Check Valves, 300 CWP:

1. Description:

- a. CWP Rating: 300 psig (2070 kPa).
- b. Body Material: ASTM A536, ductile iron.
- c. Seal: EPDM.
- d. Disc: Spring-operated, ductile iron or stainless steel.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Examine press fittings to verify they have been properly pressed.
- F. Do not attempt to repair defective valves; replace with new valves.

3.2 INSTALLATION OF VALVES

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Provide support of piping adjacent to valves such that no force is imposed upon valves.
- C. Locate valves for easy access and where not blocked by equipment, other piping, or building components.
- D. Install valves with stem at or above center of pipe.
- E. Install valves in position that does not project into aisles or block access to other equipment.
- F. Install valves in position to allow full stem and manual operator movement.
- G. Verify that joints of each valve have been properly installed and sealed to ensure that there is no leakage or damage.
- H. Install check valves for proper direction of flow and as follows:
 - 1. Swing Check Valves: In horizontal position with hinge pin level.
 - 2. Lift Check Valves: With stem upright and plumb.
- I. Install valve tags. Comply with requirements for valve tags and schedules in Section 230553 "Identification for HVAC Piping and Equipment."
- J. Adhere to manufacturer's written installation instructions. When soldering or brazing valves, do not heat valves above maximum permitted temperature. Do not use solder with melting point temperature above valve of manufacturer's recommended maximum.

3.3 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service, but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valve applications are not indicated, use the following:
 - 1. Pump-Discharge Check Valves:
 - a. **NPS 2 (DN 50)** and Smaller: Bronze swing check valves with [**bronze**] disc.
 - b. **NPS 2-1/2 (DN 65)** and Larger: Iron swing check valves with lever and weight or with spring or iron, center-guided, [**metal**] -seat check valves.
- B. If valves with specified SWP classes or CWP ratings are unavailable, the same types of valves with higher SWP classes or CWP ratings may be substituted.

C. End Connections:

1. For Copper Tubing, **NPS 2 (DN 50)** and Smaller: Threaded ends, except where solder-joint or press valve-end option is indicated in valve schedules.
2. For Copper Tubing, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends, except where threaded valve-end option is indicated in valve schedules.
3. For Copper Tubing, **NPS 5 (DN 125)** and Larger: Flanged ends.
4. For Steel Piping, **NPS 2 (DN 50)** and Smaller: Threaded ends.
5. For Steel Piping, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends, except where threaded valve-end option is indicated in valve schedules.
6. For Steel Piping, **NPS 5 (DN 125)** and Larger: Flanged ends.
7. For Grooved-End [**Copper Tubing**] [**and**] [**Steel Piping**], except Steam and Steam Condensate Piping: Valve ends may be grooved.
8. Wafer-Type Valves: Flanged connections.

3.5 CHILLED-WATER VALVE SCHEDULE

A. Pipe **NPS 2 (DN 50)** and Smaller:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Bronze swing check valves with [**bronze**] disc [**Class 150**].

B. Pipe **NPS 2-1/2 (DN 65)** and Larger:

1. **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Iron valves may be provided with threaded ends instead of flanged ends.
2. **NPS 3 to NPS 12 (DN 80 to DN 300)**: Iron, grooved-end swing check valves, 300 CWP.
3. Iron swing check valves with [**metal**] seats, [**Class 250**].
4. Iron, dual-plate check valves with resilient seat, [**Class 300**].

3.6 HEATING-WATER VALVE SCHEDULE

A. Pipe **NPS 2 (DN 50)** and Smaller:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Bronze swing check valves with [**bronze**] disc, [**Class 150**].

B. Pipe **NPS 2-1/2 (DN 65)** and Larger:

1. **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Iron valves may be provided with threaded ends instead of flanged ends.
2. **NPS 3 to NPS 12 (DN 80 to DN 300)**: Iron, grooved-end check valves, 300 CWP.
3. Iron swing check valves with [**metal**] seats, [**Class 250**].
4. Iron, dual-plate check valves with resilient seat, [**Class 300**].

3.7 HIGH-PRESSURE STEAM VALVE SCHEDULE - MORE THAN 15 PSIG (104 kPa)

A. Pipe NPS 2 (DN 50) and Smaller:

1. Bronze swing check valves with [bronze] disc [Class 150].

B. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron Valves, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): May be provided with threaded ends instead of flanged ends.
2. Iron swing check valves with [metal] seats, [Class 250].

3.8 STEAM-CONDENSATE VALVE SCHEDULE

A. Pipe NPS 2 (DN 50) and Smaller:

1. Bronze swing check valves with [bronze] disc, [Class 150].

B. Pipe NPS 2-1/2 (DN 65) and Larger:

1. NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Iron valves may be provided with threaded ends instead of flanged ends.
2. Iron swing check valves with [metal] seats, [Class 250].

END OF SECTION 230523.14

SECTION 230523.15 - GATE VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Bronze gate valves.
2. Iron gate valves.
3. Chainwheels.

1.2 DEFINITIONS

- A. CWP: Cold working pressure.
- B. NRS: Nonrising stem.
- C. OS&Y: Outside screw and yoke.
- D. RS: Rising stem.
- E. SWP: Steam working pressure.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of valve.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:

1. Protect internal parts against rust and corrosion.
2. Protect threads, flange faces, grooves, press connections, and weld ends.
3. Set gate valves closed to prevent rattling.

B. Use the following precautions during storage:

1. Maintain valve end protection.
2. Store valves indoors and maintain at higher-than-ambient-dew-point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.

- C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels, stems, or other components as lifting or rigging points unless specifically indicated for this purpose in manufacturer's written instructions.

PART 2 - PRODUCTS

2.1 SOURCE LIMITATIONS

- A. Obtain each type of valve from single source from single manufacturer.

2.2 PERFORMANCE REQUIREMENTS

- A. ASME Compliance:
 - 1. ASME B1.20.1 for threads for threaded-end valves.
 - 2. ASME B16.1 for flanges on iron valves.
 - 3. ASME B16.5 for flanges on metric standard piping.
 - 4. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 5. ASME B16.18 for cast copper solder joint.
 - 6. ASME B16.22 for wrought copper solder joint.
 - 7. ASME B16.34 for flanged, threaded, and welding ends.
 - 8. ASME B16.51 for press joint.
 - 9. ASME B31.1 for power piping valves.
 - 10. ASME B31.9 for building services piping valves.
- B. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.
- C. Provide bronze valves made with dezincification-resistant materials. Bronze valves made with copper alloy (brass) containing more than 15 percent zinc are unacceptable.
- D. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- E. Valve Sizes: Same as upstream piping unless otherwise indicated.
- F. RS Valves in Insulated Piping: With 2-inch (50-mm) stem extensions.
- G. Valve Bypass and Drain Connections: MSS SP-45.

2.3 BRONZE GATE VALVES

- A. Bronze Gate Valves, RS, Class 150:
 - 1. Description:
 - a. Standard: MSS SP-80, Type 2.
 - b. CWP Rating: 300 psig (2070 kPa).
 - c. Body Material: ASTM B62, bronze with integral seat and union-ring bonnet.
 - d. Ends: Threaded.
 - e. Stem: Bronze.
 - f. Disc: Solid wedge; bronze.
 - g. Packing: Asbestos free.
 - h. Handwheel: Malleable iron[, bronze, or aluminum].

2.4 IRON GATE VALVES

A. Iron Gate Valves, OS&Y, Class 250:

1. Description:
 - a. Standard: MSS SP-70, Type I.
 - b. **NPS 2-1/2 to NPS 12 (DN 65 to DN 300)**, CWP Rating: **500 psig (3450 kPa)**.
 - c. **NPS 14 to NPS 24 (DN 350 to DN 600)**, CWP Rating: **300 psig (2070 kPa)**.
 - d. Body Material: ASTM A126, gray iron with bolted bonnet.
 - e. Ends: Flanged.
 - f. Trim: Bronze.
 - g. Disc: Solid wedge.
 - h. Packing and Gasket: Asbestos free.

2.5 CHAINWHEELS

A. Description: Valve actuation assembly with sprocket rim, chain guides, chain[, and **attachment brackets for mounting chainwheels directly to handwheels**].

1. Sprocket Rim with Chain Guides: [**Ductile or cast iron**] [**Bronze**], of type and size required for valve.[**Include zinc or epoxy coating.**]
2. Chain: [**Hot-dip galvanized steel**] [**Brass**] [**Stainless steel**], of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Examine press joint surfaces. Verify that they are clean and free from dents and burrs and that O-ring seals are in place and undamaged.
- F. Do not attempt to repair defective valves; replace with new valves.

3.2 INSTALLATION OF VALVES

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Provide support of piping adjacent to valves such that no force is imposed upon valves.
- C. Locate valves for easy access and where not blocked by equipment, other piping, or building components.
- D. Install valves so that stems are horizontal or slope upward from centerline of pipe.
- E. Install valves in position that does not project into aisles or block access to other equipment.
- F. Install valves in position to allow full stem and manual operator movement.
- G. Verify that joints of each valve have been properly installed and sealed to ensure that there is no leakage or damage.
- H. Install chainwheels on manual operators for gate valves [NPS 4 (DN 100)] and larger and more than [96 inches (2400 mm)] above floor. Extend chains to [60 inches (1520 mm)] above finished floor.
- I. Install valve tags. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.
- J. Adhere to manufacturer's written installation instructions. When soldering or brazing valves, do not heat valves above maximum permitted temperature. Do not use solder with melting point temperature above valve of manufacturer's recommended maximum.

3.3 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service, but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valve applications are not indicated, use the following:
 - 1. Shutoff Service: Gate valves.
- B. If valves with specified SWP classes or CWP ratings are unavailable, the same types of valves with higher SWP classes or CWP ratings may be substituted.
- C. Select valves, except wafer types, with the following end connections:
 - 1. For Copper Tubing, NPS 2 (DN 50) and Smaller: Threaded ends, except where solder-joint or press valve-end option is indicated in valve schedules.
 - 2. For Copper Tubing, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Flanged ends, except where threaded valve-end option is indicated in valve schedules.

3. For Copper Tubing, **NPS 5 (DN 125)** and Larger: Flanged ends.
4. For Steel Piping, **NPS 2 (DN 50)** and Smaller: Threaded ends.
5. For Steel Piping, **NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**: Flanged ends, except where threaded valve-end option is indicated in valve schedules.
6. For Steel Piping, **NPS 5 (DN 125)** and Larger: Flanged ends.
7. For Grooved-End [**Copper Tubing**] [**and**] [**Steel Piping**], except for Steam and Steam Condensate Piping: Valve ends may be grooved.

3.5 CHILLED-WATER VALVE SCHEDULE

- A. Pipe **NPS 2 (DN 50)** and Smaller: Bronze valves, [**RS**], [**Class 150**], with [**threaded**] ends.
- B. Pipe **NPS 2-1/2 (DN 65)** and Larger: Iron gate valves, [**OS&Y**], [**Class 250**].

3.6 HEATING-WATER VALVE SCHEDULE

- A. Pipe **NPS 2 (DN 50)** and Smaller: Bronze valves, [**RS**], [**Class 150**] with [**threaded**] ends.
- B. Pipe **NPS 2-1/2 (DN 65)** and Larger: Iron gate valves, [**OS&Y**], [**Class 250**].

3.7 HIGH-PRESSURE STEAM VALVE SCHEDULE - MORE THAN **15 PSIG (104 kPa)**

- A. Pipe **NPS 2 (DN 50)** and Smaller: Bronze gate valves, [**RS**], [**Class 150**].
- B. Pipe **NPS 2-1/2 (DN 65)** and Larger: Iron gate valves, [**OS&Y**], [**Class 250**].

3.8 STEAM-CONDENSATE VALVE SCHEDULE

- A. Pipe **NPS 2 (DN 50)** and Smaller: Bronze gate valves, [**RS**], [**Class 150**].
- B. Pipe **NPS 2-1/2 (DN 65)** and Larger: Iron gate valves, [**OS&Y**], [**Class 250**].

END OF SECTION 230523.15

SECTION 230529 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Metal pipe hangers and supports.
2. Trapeze pipe hangers.
3. Metal framing systems.
4. Thermal-hanger shield inserts.
5. Fastener systems.
6. Pipe stands.
7. Equipment stands.
8. Equipment supports.

B. Related Requirements:

1. Section 055000 "Metal Fabrications" for structural-steel shapes and plates for trapeze hangers for pipe and equipment supports.
2. Section 230516 "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
3. [Section 230548 "Vibration and Seismic Controls for HVAC"] [Section 230548.13 "Vibration Controls for HVAC"] for vibration isolation devices.
4. [Section 233113 "Metal Ducts"] for duct hangers and supports.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

- B. Shop Drawings: **[Signed and sealed by a qualified professional engineer.]** Show fabrication and installation details and include calculations for the following; include Product Data for components:

1. Trapeze pipe hangers.
2. Metal framing systems.
3. Fiberglass strut systems.
4. Pipe stands.
5. Equipment supports.

- 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. Include design calculations for designing trapeze hangers.

1.4 INFORMATIONAL SUBMITTALS

- A. 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, Section IX.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design trapeze pipe hangers and equipment supports.
- 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. Design seismic-restraint hangers and supports for piping and equipment [**and obtain approval from authorities having jurisdiction**].

2.2 METAL PIPE HANGERS AND SUPPORTS

- A. Carbon-Steel Pipe Hangers and Supports:
 - 1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
 - 2. Galvanized Metallic Coatings: Pregalvanized, hot-dip galvanized, or electro-galvanized.
 - 3. Nonmetallic Coatings: Plastic coated, or epoxy powder-coated.
 - 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 [**stainless steel**].

B. Copper Pipe and Tube Hangers:

1. Description: MSS SP-58, Types 1 through 58, copper-plated steel, factory-fabricated components.
2. Hanger Rods: Continuous-thread rod, nuts, and washer made of [**stainless steel**].

2.3 TRAPEZE PIPE HANGERS

- A. Description: MSS SP-58, 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.

2.4 METAL FRAMING SYSTEMS

A. MFMA Manufacturer Metal Framing Systems:

1. Description: Shop- or field-fabricated, pipe-support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.
2. Standard: Comply with MFMA-4 factory-fabricated components for field assembly.
3. Channels: Continuous slotted [**carbon-steel**] channel with inturned lips.
4. Channel Width: Selected for applicable load criteria.
5. Channel Nuts: Formed or stamped 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 [**stainless steel**].
7. Metallic Coating: [**Pregalvanized G90 (Z275)**].

B. Non-MFMA Manufacturer Metal Framing Systems:

1. Description: Shop- or field-fabricated, pipe-support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.
2. Standard: Comply with MFMA-4 factory-fabricated components for field assembly.
3. Channels: Continuous slotted [**carbon-steel**] channel with inturned lips.
4. Channel Width: Select for applicable load criteria.
5. Channel Nuts: Formed or stamped 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 [**stainless steel**].
7. Metallic Coating: [**Pregalvanized G90 (Z275)**].

2.5 THERMAL-HANGER SHIELD INSERTS

- A. Insulation-Insert Material for Cold Piping: [**ASTM C591, Type VI, Grade 1 polyisocyanurate with 125-psi (862-kPa)**] minimum compressive strength and vapor barrier.
- B. Insulation-Insert Material for Hot Piping: [**ASTM C591, Type VI, Grade 1 polyisocyanurate with 125-psi (862-kPa)**] minimum compressive strength.
- C. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.
- D. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.

- E. Insert Length: Extend **2 inches (50 mm)** beyond sheet metal shield for piping operating below ambient air temperature.

2.6 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 anchors for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
 - 1. Indoor Applications: [**stainless**] steel.
 - 2. Outdoor Applications: Stainless steel.

2.7 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:
 - 1. Description: Single base unit with integral-rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.
 - 2. Base: Single, vulcanized rubber, molded polypropylene, or polycarbonate.
 - 3. Hardware: Galvanized steel or polycarbonate.
 - 4. Accessories: Protection pads.
- C. Low-Profile, Single Base, Single-Pipe Stand:
 - 1. Description: Single base with vertical and horizontal members, and pipe support, for roof installation without membrane protection.
 - 2. Base: Single, vulcanized rubber, molded polypropylene, or polycarbonate.
 - 3. Vertical Members: Two, [**galvanized**]-steel, continuous-thread **1/2-inch (12-mm)** rods.
 - 4. Horizontal Member: Adjustable horizontal, [**galvanized**]-steel pipe support channels.
 - 5. Pipe Supports: [**Strut clamps**] [**Clevis hanger**] [**Swivel hanger**].
 - 6. Hardware: [**Stainless**] steel.
 - 7. Accessories: Protection pads.
 - 8. Height: [**12 inches (300 mm)** above roof].
- D. High-Profile, Single Base, Single-Pipe Stand:
 - 1. Description: Single base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.
 - 2. Base: Single vulcanized rubber or molded polypropylene.
 - 3. Vertical Members: Two, [**galvanized**] -steel, continuous-thread **1/2-inch (12-mm)** rods.
 - 4. Horizontal Member: One, adjustable height, [**galvanized**]-steel pipe support slotted channel or plate.

5. Pipe Supports: [Clevis hanger] [Swivel hanger].
 6. Hardware: [Stainless] steel.
 7. Accessories: Protection pads [, 1/2-inch (12-mm) continuous-thread stainless steel rod].
 8. Height: [36 inches (900 mm) above roof].
- E. High-Profile, Multiple-Pipe Stand:
1. Description: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.
 2. Bases: Two or more; [vulcanized rubber].
 3. Vertical Members: Two or more, [galvanized]-steel channels.
 4. Horizontal Members: One or more, adjustable height, [galvanized]-steel pipe support.
 5. Pipe Supports: [Strut clamps] [Clevis hanger] [Swivel hanger].
 6. Hardware: [Stainless] steel.
 7. Accessories: Protection pads [, 1/2-inch (12-mm) continuous-thread stainless steel rod].
 8. Height: [36 inches (900 mm) above roof].
- F. 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.

2.8 EQUIPMENT SUPPORTS

- A. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes.

2.9 OUTDOOR EQUIPMENT STANDS

1. Description: Individual foot supports with elevated adjustable channel cross bars and clamps/fasteners/bolts for ground or roof supported outdoor equipment components, without roof membrane penetration, in a pre-fabricated system that can be modularly-assembled on site.
2. Foot Material: Rubber or polypropylene.
3. Rails Material: Hot dip galvanized carbon steel.
4. Wind/Sliding Load Resistance: Up to [100 mph (44 mps)] minimum.

2.10 MATERIALS

- A. Carbon Steel: ASTM A1011/A1011M.
- B. Structural Steel: ASTM A36/A36M, carbon-steel plates, shapes, and bars; galvanized.
- C. Stainless Steel: ASTM A240/A240M.
- D. Threaded Rods: Continuously threaded. stainless steel for indoor applications and stainless steel for outdoor applications. Mating nuts and washers of similar materials as rods.

- E. Grout: ASTM C1107/C1107M, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.
 - 1. Properties: Nonstaining, noncorrosive, and nongaseous.
 - 2. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

PART 3 - EXECUTION

3.1 APPLICATION

- A. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping materials and installation for penetrations through fire-rated walls, ceilings, and assemblies.
- B. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus [200 lb (90 kg)].

3.2 HANGER AND SUPPORT INSTALLATION

- A. Metal Pipe-Hanger Installation: Comply with MSS SP-58. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.
- B. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-58. 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 A36/A36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.
- C. Fiberglass Pipe-Hanger Installation: Comply with applicable portions of MSS SP-58. Install hangers and attachments as required to properly support piping from building structure.
- D. [Metal] Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled strut systems.
- E. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.
- F. Fastener System Installation:
 - 1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches (100 mm) 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.

G. 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 Section 077200 "Roof Accessories" for curbs.

H. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.

I. Equipment Support Installation: Fabricate from welded-structural-steel shapes.

J. Install hangers and supports to allow controlled thermal and seismic 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.

K. Install lateral bracing with pipe hangers and supports to prevent swaying.

L. 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 (DN 65)] 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.

M. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

N. 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.

O. 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 (DN 100) 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 (DN 100)** 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 (DN 8 to DN 90): 12 inches (305 mm)** long and **0.048 inch (1.22 mm)** thick.
 - b. **NPS 4 (DN 100): 12 inches (305 mm)** long and **0.06 inch (1.52 mm)** thick.
 - c. **NPS 5 and NPS 6 (DN 125 and DN 150): 18 inches (457 mm)** long and **0.06 inch (1.52 mm)** thick.
 - d. **NPS 8 to NPS 14 (DN 200 to DN 350): 24 inches (610 mm)** long and **0.075 inch (1.91 mm)** thick.
 - e. **NPS 16 to NPS 24 (DN 400 to DN 600): 24 inches (610 mm)** long and **0.105 inch (2.67 mm)** thick.
5. Pipes **NPS 8 (DN 200)** 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.

3.3 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.

3.4 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.

3.5 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 (40 mm)**].

3.6 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 (0.05 mm)**.
- B. Touchup: Comply with requirements in [**Section 099113 "Exterior Painting"**] [**Section 099123 "Interior Painting"**] [and] [**Section 099600 "High-Performance Coatings"**] <Insert painting Sections> for cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal.
- C. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A780/A780M.

3.7 HANGER AND SUPPORT SCHEDULE

- A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.
- B. Comply with MSS SP-58 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 galvanized-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 padded hangers for piping that is subject to scratching.
- H. Use thermal-hanger shield inserts for insulated piping and tubing.

- I. 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 noninsulated or insulated, stationary pipes **NPS 1/2 to NPS 30 (DN 15 to DN 750)**.
 2. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of up to **1050 deg F (566 deg C)**, pipes **NPS 4 to NPS 24 (DN 100 to DN 600)**, requiring up to **4 inches (100 mm)** of insulation.
 3. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes **NPS 3/4 to NPS 36 (DN 20 to DN 900)**, requiring clamp flexibility and up to **4 inches (100 mm)** of insulation.
 4. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes **NPS 1/2 to NPS 24 (DN 15 to DN 600)** if little or no insulation is required.
 5. Pipe Hangers (MSS Type 5): For suspension of pipes **NPS 1/2 to NPS 4 (DN 15 to DN 100)**, 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 noninsulated, stationary pipes **NPS 3/4 to NPS 8 (DN 20 to DN 200)**.
 7. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated, stationary pipes **NPS 1/2 to NPS 8 (DN 15 to DN 200)**.
 8. Adjustable Band Hangers (MSS Type 9): For suspension of noninsulated, stationary pipes **NPS 1/2 to NPS 8 (DN 15 to DN 200)**.
 9. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of noninsulated, stationary pipes **NPS 1/2 to NPS 8 (DN 15 to DN 200)**.
 10. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of noninsulated, stationary pipes **NPS 3/8 to NPS 8 (DN 10 to DN 200)**.
 11. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated, stationary pipes **NPS 3/8 to NPS 3 (DN 10 to DN 80)**.
 12. U-Bolts (MSS Type 24): For support of heavy pipes **NPS 1/2 to NPS 30 (DN 15 to DN 750)**.
 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 (DN 100 to DN 900)**, 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 (DN 100 to DN 900)**, 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 (DN 65 to DN 900)** 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 (DN 25 to DN 750)**, 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 (DN 65 to DN 600)**, 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 (DN 50 to DN 1050)** if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is unnecessary.

20. Pipe Roll and Plate Units (MSS Type 45): For support of pipes **NPS 2 to NPS 24 (DN 50 to DN 600)** if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is unnecessary.
 21. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes **NPS 2 to NPS 30 (DN 50 to DN 750)** if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.
- J. 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 (DN 24 to DN 600)**.
 2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers **NPS 3/4 to NPS 24 (DN 20 to DN 600)** if longer ends are required for riser clamps.
- K. 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 (150 mm)** for heavy loads.
 2. Steel Clevises (MSS Type 14): For **120 to 450 deg F (49 to 232 deg C)** 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 (49 to 232 deg C)** piping installations.
- L. 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-joist 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 (340 kg).
 - b. Medium (MSS Type 32): 1500 lb (680 kg).
 - c. Heavy (MSS Type 33): 3000 lb (1360 kg).
 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.
- M. 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.
- N. 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 (32 mm).
 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.

- O. Comply with MSS SP-58 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.
- P. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.
- Q. Use [**powder-actuated fasteners**] [or] [**mechanical-expansion anchors**] instead of building attachments where required in concrete construction.

END OF SECTION 230529

SECTION 230546 - COATINGS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. 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 application of coating systems on internal HVAC components and external equipment surfaces, including the following systems:
 - 1. Bake-cured corrosion-resistant coating systems.
 - 2. Air-dried corrosion-resistant coating systems.

1.3 DEFINITIONS

- A. Salt Water Acetic Acid Test (SWAAT): A salt fog-spray test of corrosion resistance performed in accordance with ASTM G85, Annex 3.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include Safety Data Sheets, preparation requirements, and application instructions.

1.5 INFORMATIONAL SUBMITTALS

- A. Source Quality-Control Reports:
 - 1. Certification of coating material testing.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Coatings: [1] [container] of each material and color applied [, **including base coat and top coat products**].

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Store materials not in use in tightly covered containers in clean, dry, well-ventilated areas with ambient temperatures continuously maintained between **50 and 75 deg F** (**10 and 24 deg C**).
1. Keep containers out of direct sunlight; avoid excessive heat and keep from freezing.
 2. Maintain containers in clean condition, free of foreign materials and residue.
 3. Remove rags and waste from storage areas daily.

1.8 CONDITIONS FOR COATING APPLICATION

- A. Comply with manufacturer's recommendations regarding required temperature and humidity ranges during coating application.

PART 2 - PRODUCTS

2.1 CORROSION-RESISTANT COATING SYSTEMS, GENERAL

- A. Material Compatibility:
1. Provide materials for application within each coating system that are compatible with one another and with metal substrates indicated, under conditions of service and application as demonstrated by manufacturer, based on testing and field experience.
 2. For each coating material in coating system, submit compatibility certification from manufacturer of each coating product that products are compatible with substrate base material and with substrate-coating products applied as earlier coats.
 3. Products shall be of same manufacturer for each coat in a coating system.
- B. Colors: [**Manufacturer's standard**].

2.2 BAKE-CURED CORROSION-RESISTANT COATING SYSTEMS

- A. Base Coat Performance Requirements:
1. Corrosion Resistance: ASTM B117: [**6000**] hours.
 2. Cross-Hatch Adhesion: ASTM D3359: [**5B**].
 3. SWAAT: ASTM G85: [**1000**] hours.
 4. Cyclic Weathering: ISO 12944-9, [**4200**] hours.
 5. Mandrel Flexibility: ASTM D522/D522M: [**1/2 inch (13 mm)**] without cracking or delamination of film after full cure.
 6. Adhesion - Elcometer: ASTM D4541: [**1100 psi (7.6 MPa)**].
 7. Impact: ASTM D2794.
 - a. Direct Hit: [**90 lb.-in. (10.2 N-m)**].
 - b. Reverse Hit: [**40 lb.-in. (4.5 N-m)**].

8. pH Range, 14-Day Liquid Spot Test: [**3 to 12**].
 9. Dry Heat Resistance: ASTM D2485: [**392 deg F (200 deg C)**] <Insert value> maximum.
 10. Dry Film Thickness: [**0.6 to 1.5 mils (0.015 to 0.038 mm)**].
 11. Heat-Transfer Reduction: [**1 percent maximum**].
 12. Hardness: ASTM D3363 Pencil Test: [**5H-6H**].
- B. Bake-Cured Coating Acceptable for Equipment Serving Food-Preparation Areas: In accordance with NSF 51.
- C. Bake-Cured Top Coat Performance Requirements: Provide product with UV shielding properties, color stability, and maintenance of manufacturer's standard sheen, after exposure to outdoor conditions.
- D. Bake-Cured, Immersion-Applied Phenolic Epoxy System.
- E. Baked-Cured, Immersion-Applied Epoxy Coating System.

2.3 AIR-DRIED CORROSION-RESISTANT COATING SYSTEMS

- A. Performance Requirements:
1. Corrosion Resistance: ASTM B117: [**6000**] hours.
 2. Cross-Hatch Adhesion: ASTM D3359: [**5B**].
 3. Cyclic Weathering: ISO 12944-9, Offshore Standard: [**4200**] hours.
 4. Mandrel Flexibility: ASTM D522/D522M: [**1/2 inch (13 mm)**] without cracking or delamination of film after full cure.
 5. Impact: ASTM D2794.
 - a. Direct Hit: [**100 in-lb (11.3 N-m)**].
 6. Dry Heat Resistance: ASTM D2485: [**356 deg F (180 deg C)**] maximum.
 7. Dry Film Thickness: [**2 to 3 mils (0.050 to 0.075 mm)**].
 8. Heat-Transfer Reduction: [**1 percent**] maximum.
 9. Hardness: ASTM D3363 Pencil Test: [**2B-HB**].
- B. Air-Dried, Spray-Applied Principle Coating System.
- C. Air-Dried Phenolic System.
- D. Air-Dried, Spray-Applied Coating System.
- E. Air-Dried, Spray-Applied, Polyurethane Mixed with Aluminum Flakes System.
- F. Base Coat Performance Requirements:
1. Corrosion Resistance: ASTM B117: [**6000**] hours.
 2. SWAAT: ASTM G85: [**1000**] hours.
 3. Cyclic Weathering: ISO 12944-9: [**4200**] hours.
 4. Cross-Hatch Adhesion: ASTM D3359: [**5B**].

5. Mandrel Flexibility: ASTM D522/D522M: [**1/2 inch (13 mm)**] without cracking or delamination of film after full cure.
6. Adhesion - Elcometer: ASTM D4541: [**1,100 psi (7.6 MPa)**].
7. Impact: ASTM D2794.
 - a. Direct Hit: [**100 lb.-in. (11.3 N-m)**].
8. Dry Heat Resistance: ASTM D2485: [**250 deg F (121 deg C)**] maximum.
9. Dry Film Thickness: [**0.6 to 1.5 mils (0.015 to 0.038 mm)**].
10. Heat-Transfer Reduction: [**1 percent**] maximum.
11. Hardness: ASTM D3363 Pencil Test: [**2B-HB**].
- G. Air-Dried Coating Acceptable for Equipment Serving Food-Preparation Areas": In accordance with 21 CFR 175.300.
- H. Air-Dried Top Coat Performance Requirements: Provide product with UV shielding properties, color stability, and maintenance of manufacturer's standard sheen, after exposure to outdoor conditions.
- I. Spray-Can Application Systems:
 1. Type: Air dry, phenolic.

2.4 SOURCE QUALITY CONTROL

- A. Certification of Coating Material Testing: Submit manufacturer's test report of corrosion-resistance performance testing, as performed by a nationally recognized testing laboratory.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Applicator present, for compliance with coating manufacturer's requirements and other conditions affecting performance of the Work.
- B. Verify suitability of substrates, including surface conditions and compatibility, with existing finishes and primers.
- C. Proceed with coating application only after unsatisfactory conditions have been corrected.
 1. Application of coating indicates acceptance of surfaces and conditions.

3.2 PREPARATION

- A. Comply with manufacturer's written instructions applicable to substrates and coating systems indicated.
 - 1. Thinning: Thin coating material with manufacturer's recommended thinning products when recommended or permitted by coating system manufacturer.
- B. Comply with coating system manufacturer's recommendations to clean substrates of substances that could impair bond of coatings, including dust, dirt, oil, grease, and incompatible paints and encapsulants.

3.3 APPLICATION

- A. Verify with coating manufacturer whether coatings required must be applied and cured in factory-certified application shop.
- B. Apply coating systems with equipment designed to deposit coating of specified uniform thickness over HVAC components, in complex, three-dimensional geometries.
 - 1. Apply coatings with manufacturer-recommended tools and techniques suited for specified coating system and each coated HVAC component.
 - 2. Do not apply coatings over labels or equipment name, identification, performance rating, or nomenclature plates.
- C. Perform inspection and coating system manufacturer's recommended tests to verify coating integrity and thickness. Where coating was damaged by testing, repair damage in accordance with coating system manufacturer's written recommendations.

END OF SECTION 230546

SECTION 230548.13 - VIBRATION CONTROLS FOR HVAC

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. Elastomeric isolation pads.
2. Elastomeric isolation mounts.
3. Restrained elastomeric isolation mounts.
4. Open-spring isolators.
5. Housed-spring isolators.
6. Restrained-spring isolators.
7. Housed-restrained-spring isolators.
8. Pipe-riser resilient support.
9. Resilient pipe guides.
10. Air-spring isolators.
11. Restrained-air-spring isolators.
12. Elastomeric hangers.
13. Spring hangers.
14. Snubbers.
15. Restraints - rigid type.
16. Restraints - cable type.
17. Restraint accessories.
18. Post-installed concrete anchors.
19. Concrete inserts.
20. Vibration isolation equipment bases.
21. Restrained isolation roof-curb rails.

B. Related Requirements:

1. Section 210548.13 "Vibration Controls for Fire-Suppression Piping and Equipment" for devices for fire-suppression equipment and systems.
2. Section 220548.13 "Vibration Controls for Plumbing Piping and Equipment" for devices for plumbing equipment and systems.

1.3 DEFINITIONS

- A. IBC: International Building Code.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
2. Include load rating for each wind-force-restraint fitting and assembly.
3. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of vibration isolation device [**and wind-force-restraint**] component.
4. Annotate to indicate application of each product submitted and compliance with requirements.
5. Interlocking Snubbers: Include ratings for horizontal, vertical, and combined loads.

B. Shop Drawings:

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

C. Delegated-Design Submittal:

1. For each wind-load protection device that is required by this Section or is indicated on Drawings, submit the following:
 - a. Vibration Isolator and Wind-Load-Restraint Selection: Select vibration isolators, wind-load restraints, and vibration isolation bases complying with performance requirements, design criteria, and analysis data.
 - b. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, and spring deflection changes. Include certification by professional engineer that riser system was examined for excessive stress and that none exists.
 - c. Concrete Anchors and Inserts: Include calculations showing anticipated wind loads.
 - d. Wind-Load Design Calculations: Submit all static and dynamic loading calculations prepared under "Wind-Load Design Calculations" Paragraph in "Performance Requirements" Article.
 - e. Qualified Professional Engineer: All designated-design submittals for wind-restraint calculations are to be signed and sealed by qualified professional engineer responsible for their preparation.
2. Wind-Restraint Detail Drawing:
 - a. Design Analysis: To support selection and arrangement of wind restraints. Include calculations of combined tensile and shear loads.
 - b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during wind events. Indicate association with vibration isolation devices.

- c. Coordinate vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply also with requirements in other Sections for equipment mounted outdoors.
3. All delegated-design submittals for wind-restraint detail Drawings are to be signed and sealed by qualified professional engineer responsible for their preparation.
4. Product Listing, Preapproval, and Evaluation Documentation: By **[[UL] [FM Approvals] [an agency acceptable to authorities having jurisdiction]**, showing maximum ratings of restraint items and basis for approval (tests or calculations).
5. Design Calculations for Vibration Isolation Devices: Calculate static and dynamic loading due to equipment weight and operating forces required to select proper vibration isolators, and to design vibration isolation bases.
6. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, and spring deflection changes. Include certification that riser system was examined for excessive stress and that none exists.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Show coordination of vibration isolation device installation for HVAC piping and equipment with other systems and equipment in the vicinity, including other supports and restraints.
- B. Qualification Data: For testing agency.
- C. Welding certificates.
- D. Air-Spring Mounting System Performance Certification: Include natural frequency, load, and damping test data **[performed by an independent agency]**.
- E. Field quality-control reports.
- F. Wind-Force Performance Certification: Provide special certification for HVAC components subject to high wind exposure and impact damage and designated on Drawings or in the Specifications to require wind-force performance certification.
 1. Provide equipment manufacturer's written certification for each designated HVAC device, stating that it will remain in place and operable following the design wind event and comply with all requirements of authorities having jurisdiction.
 2. Provide manufacturer's written certification for each designated louver, damper, or similar device, stating that it will remain in place and protect opening from penetration of windborne debris and comply with all requirements of authorities having jurisdiction.
 3. Certification must be based on ICC-ES or similar nationally recognized testing standard procedures acceptable to authorities having jurisdiction.
 4. The following HVAC systems and components require special certification for high wind performance. Written special certification of resistance to the effects of high wind force and impact damage must be provided by manufacturer.

1.6 CLOSEOUT SUBMITTALS

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

1.7 QUALITY ASSURANCE

- A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct testing indicated, be an NRTL as defined by OSHA in 29 CFR 1910.7 and be acceptable to authorities having jurisdiction.
- B. Welding Qualifications: Qualify procedures and personnel in accordance with AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- C. Wind-Load-Restraint Device Load Ratings: Devices to be tested and rated in accordance with applicable code requirements and authorities having jurisdiction. Devices to be listed by a nationally recognized third party that requires periodic follow-up inspections and has a listing directory available to the public. Provide third-party listing by one or more of the following: **[UL product listing]** **[FM Approvals]** **[an agency acceptable to authorities having jurisdiction]**.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design system.
 - 1. Wind-Load Performance: Equipment shall withstand the effects of high wind events determined in accordance with **[ASCE/SEI 7-10]**.
- B. Wind-Load Design Calculations:
 - 1. Perform calculations to obtain force information necessary to properly select wind-load-restraint devices, fasteners, and anchorage. Perform calculations using methods acceptable to applicable code authorities and as presented in **[ASCE/SEI 7-10]**. Where "ASCE/SEI 7" is used throughout this Section, it is to be understood that the edition referred to in this subparagraph is intended as referenced throughout the Section Text unless otherwise noted.
 - a. Factors indicated below that are specific to individual pieces of equipment must be obtained by Contractor and must be included in individual component submittal packages.
 - b. Coordinate design wind-load calculations with vibration isolation requirements. Comply with requirements in other Sections in addition to those in this Section for equipment mounted outdoors.

2. Design wind pressure "p" for external sidewall-mounted equipment such as louvers are to be calculated by Delegated-Design Contractor using methods in ASCE/SEI 7-10, Ch. 30. Perform calculations in accordance with one of the following, as appropriate:
 - a. PART 1: Low-Rise Buildings.
 - b. PART 2: Low-Rise Buildings (Simplified).
 - c. PART 3: Buildings with "h" greater than **60 feet (18.3 m)**.
 - d. PART 4: Buildings with "h" less than **160 feet (48.8 m)**.
 - e. PART 5: Open Buildings.

3. Design wind pressure "p" for rooftop equipment is to be calculated by Delegated-Design Contractor using methods in ASCE/SEI 7-10, Ch. 30, PART 6: Building Appurtenances and Rooftop Structures and Equipment.
 - a. Risk Category: **[MALL]**.
 - b. h = Mean Roof Height: **<as per drawings>**.
 - c. V = Basic Wind Speed: **<RIYADH >**.
 - d. K_d = Wind Directionality Factor: **< RIYADH >**.
 - e. Exposure Category: **[RIYADH]**.
 - f. K_{zt} = Topographic Factor.
 - g. K_z = Velocity Pressure Exposure Coefficient (Evaluated at Height z).
 - h. K_h = Velocity Pressure Exposure Coefficient (Evaluated at Height h).
 - i. q_z = Velocity Pressure at Height z: Value calculated by delegated wind-load design Contractor using methods detailed in ASCE/SEI 7-10 Section 26.10.1 or other source approved by authorities having jurisdiction.
 - j. q_h = Velocity Pressure at Height h: Value calculated by delegated wind-load design Contractor using methods detailed in ASCE/SEI 7-10 Section 26.10.1 or other source approved by authorities having jurisdiction.
 - k. G = Gust-Effect Factor: **[0.85]**.
 - l. Enclosure Classification: **<as per structural>**.
 - m. GC_{pi} = Internal Pressure Coefficient: **<as per structural>**.

- C. Consequential Damage: Provide additional restraints for suspended HVAC components or anchorage of floor-, roof-, or wall-mounted HVAC components as indicated in **[ASCE/SEI 7-10]** so that failure of a non-essential or essential HVAC component will not cause the failure of any other essential architectural, mechanical, or electrical building component.

- D. Fire/Smoke Resistance: All components that are not constructed of ferrous metals must have a maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested by an NRTL in accordance with ASTM E84 or UL 723, and be so labeled.

- E. Component Supports:
 1. Load ratings, features, and applications of all reinforcement components must be based on testing standards of a nationally recognized testing agency.

2.2 ELASTOMERIC ISOLATION PADS

A. Elastomeric Isolation Pads:

1. Fabrication: Single or multiple layers of sufficient durometer stiffness for uniform loading over pad area.
2. Size: Factory or field cut to match requirements of supported equipment.
3. Minimum deflection as indicated on Drawings.
4. Pad Material: Oil- and water-resistant rubber.
5. Infused nonwoven cotton or synthetic fibers.
6. Load-bearing metal plates adhered to pads.
7. Sandwich-Core Material: **[Resilient] [and] [elastomeric]**.
 - a. Infused nonwoven cotton or synthetic fibers.

2.3 ELASTOMERIC ISOLATION MOUNTS

A. Elastomeric Isolation Mounts:

1. Mounting Plates:
 - a. Top Plate: Encapsulated steel load transfer top plates, factory drilled and threaded **[with threaded studs or bolts]**.
 - b. Baseplate: Encapsulated steel bottom plates with holes provided for anchoring to support structure.
2. Minimum deflection as indicated on Drawings.
3. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.4 RESTRAINED ELASTOMERIC ISOLATION MOUNTS

A. Restrained Elastomeric Isolation Mounts:

1. Description: All-directional isolator with restraints containing two separate and opposing elastomeric elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.
 - a. Housing: Cast-ductile iron or welded steel.
 - b. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.
2. Minimum deflection as indicated on Drawings.

2.5 OPEN-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators:

1. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
2. Minimum Additional Travel: 50 percent of the required deflection at rated load.
3. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
4. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
5. Baseplates: Factory-drilled steel plate for bolting to structure with an elastomeric isolator pad attached to the underside. Baseplates shall limit floor load to **500 psi (3447 kPa)**.
6. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.
7. Minimum deflection as indicated on Drawings.

2.6 HOUSED-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators in Two-Part Telescoping Housing:

1. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
2. Minimum Additional Travel: 50 percent of the required deflection at rated load.
3. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
4. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
5. Minimum deflection as indicated on Drawings.
6. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators.
 - a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to **500 psi (3447 kPa)**.
 - b. Top housing with **[threaded mounting holes and internal leveling device] [elastomeric pad]**.

2.7 RESTRAINED-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators with Vertical-Limit Stop Restraint:

1. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.
 - a. Base with holes for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to **500 psi (3447 kPa)**.
 - b. Top plate with **[threaded mounting holes] [elastomeric pad]**.
 - c. Internal leveling bolt that acts as blocking during installation.

2. Restraint: 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.
7. Minimum deflection as indicated on Drawings.

2.8 HOUSED-RESTRAINED-SPRING ISOLATORS

A. Freestanding, Steel, Open-Spring Isolators with Vertical-Limit Stop Restraint in Two-Part Telescoping Housing:

1. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators. Housings are equipped with [adjustable] snubbers to limit vertical movement.
 - a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psi (3447 kPa).
 - b. Threaded top housing with adjustment bolt and cap screw to fasten and level equipment.
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. Minimum deflection as indicated on Drawings.

2.9 PIPE-RISER RESILIENT SUPPORT

A. All-Directional, Acoustical Pipe Anchor Consisting of Two Steel Tubes Separated by a Minimum 1/2-inch- (13-mm-) Thick Neoprene:

1. Vertical-Limit Stops: Steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions.
2. Maximum Load Per Support: 500 psi (3447 kPa) on isolation material providing equal isolation in all directions.
3. Minimum deflection as indicated on Drawings.

2.10 RESILIENT PIPE GUIDES

- A. Telescopic Arrangement of Two Steel Tubes or Post and Sleeve Arrangement Separated by a Minimum **1/2-inch- (13-mm-)** Thick Neoprene:
1. Factory-Set Height Guide with Shear Pin: Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.11 AIR-SPRING ISOLATORS

- A. Freestanding, Single or Multiple, Compressed-Air Bellows:
1. Bellows Assembly: Upper and lower powder-coated steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows or similar elastomeric material.
 2. Maximum Natural Frequency: 3 Hz.
 3. Operating Pressure Range: **25 to 100 psi (172 to 690 kPa)**.
 4. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
 5. Minimum deflection as indicated on Drawings.
 6. Automatic leveling valve.

2.12 RESTRAINED-AIR-SPRING ISOLATORS

- A. Freestanding, Single or Multiple, Compressed-Air Bellows with Vertical-Limit Stop Restraint:
1. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.
 - a. Base with holes for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to **500 psi (3447 kPa)**.
 - b. Top plate with [**threaded mounting holes**] [**elastomeric pad**].
 - c. Internal leveling bolt that acts as blocking during installation.
 2. Restraint: Limit stop as required for equipment and authorities having jurisdiction.
 3. Minimum deflection as indicated on Drawings.
 4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
 5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
 6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
 7. Bellows Assembly: Upper and lower powder-coated steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows or similar elastomeric material.
 8. Maximum Natural Frequency: 3 Hz.
 9. Operating Pressure Range: **25 to 100 psi (172 to 690 kPa)**.
 10. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
 11. Automatic leveling valve.

2.13 ELASTOMERIC HANGERS

A. Elastomeric Mount in a Steel Frame with Upper and Lower Steel Hanger Rods:

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

2.14 SPRING HANGERS

A. Combination Coil-Spring and Elastomeric-Insert Hanger with Spring and Insert in Compression:

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. Minimum deflection as indicated on Drawings.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
7. Elastomeric Element: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.
8. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
9. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

2.15 SNUBBERS

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

1. Post-Installed Concrete Anchor Bolts: Secure to concrete surface with post-installed concrete anchors. Anchors to be prequalified in accordance with ACI 355.2 testing and designated in accordance with [ACI 318-14 Ch. 17 for 2015 or 2018 IBC].
2. Preset Concrete Inserts: Prequalified in accordance with ICC-ES AC446 testing.
3. Anchors in Masonry: Design in accordance with TMS 402.
4. Resilient Isolation Washers and Bushings: Oil- and water-resistant neoprene.
5. Resilient Cushion: Maximum 1/4-inch (6-mm) air gap, and minimum 1/4 inch (6 mm) thick.

2.16 RESTRAINTS - RIGID TYPE

- A. Description: Shop- or field-fabricated bracing assembly made of AISI S110-07-S1 slotted steel channels, ANSI/ASTM A53/A53M steel pipe as per NFPA 13, or other rigid steel brace member. Includes accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; rated in tension, compression, and torsion forces.

2.17 RESTRAINTS - CABLE TYPE

- A. Restraint Cables: [**ASTM A492 stainless steel**] cables. End connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; with fittings attached by means of poured socket, swaged socket, or mechanical (Flemish eye) loop.
- B. Restraint cable assembly and cable fittings must comply with [**ASCE/SEI 19-10**]. All cable fittings and complete cable assembly must maintain the minimum cable breaking force. U-shaped cable clips and wedge-type end fittings do not comply and are unacceptable.

2.18 RESTRAINT ACCESSORIES

- A. Hanger-Rod Stiffener: [**Reinforcing steel angle clamped**] to hanger rod.
- B. Hinged and Swivel Brace Attachments: Multifunctional steel connectors for attaching hangers to [**rigid channel bracings**] [**and**] [**restraint cables**].
- C. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchor bolts and studs.
- D. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings, and matched to type and size of attachment devices used.
- E. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

2.19 POST-INSTALLED CONCRETE ANCHORS

- A. Mechanical Anchor Bolts:
 - 1. Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength for anchor and as tested according to ASTM E488/E488M.

B. Adhesive Anchor Bolts:

1. Drilled-in and capsule anchor system containing PVC or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E488/E488M.

C. Provide post-installed concrete anchors that have been prequalified for use in wind-load applications. Post-installed concrete anchors must comply with all requirements of [ASCE/SEI 7-10, Ch. 13].

1. Prequalify post-installed anchors in concrete in accordance with ACI 355.2 or other approved qualification testing procedures.
2. Prequalify post-installed anchors in masonry in accordance with approved qualification procedures.

2.20 CONCRETE INSERTS

- A. Provide preset concrete inserts that are prequalified in accordance with ICC-ES AC466 testing.
- B. Comply with ANSI/MSS SP-58.

2.21 VIBRATION ISOLATION EQUIPMENT BASES

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

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide rails.
 - a. Include supports for suction and discharge elbows for pumps.
2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A36/A36M. Rails shall have shape to accommodate supported equipment.
3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

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

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) 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 A36/A36M. Bases shall have shape to accommodate supported equipment.

3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
- C. Concrete Inertia Base: [**Factory-fabricated**] [or] [**field-fabricated**], welded, structural-steel bases and rails ready for placement of cast-in-place concrete.
1. Design Requirements: Lowest possible mounting height with not less than **1-inch (25-mm)** 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 A36/A36M. Bases shall have shape to accommodate supported equipment.
 3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
 4. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.

2.22 RESTRAINED ISOLATION ROOF-CURB RAILS

- A. Description: Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment.
- B. Upper Frame: Shall provide continuous and captive support for equipment.
- C. Lower Support Assembly: Shall be formed sheet metal section containing adjustable and removable steel springs that support upper frame. 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 (50 mm)** of rigid glass-fiber insulation on inside of assembly.
1. Adjustable, restrained-spring isolators shall be mounted on elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with integrity of roof.
 2. Minimum deflection as indicated on Drawings.
- D. Water Seal: Galvanized sheet metal with EPDM seals at corners, attached to upper support frame, extending down past wood nailer of lower support assembly, and counterflashed over roof materials.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and equipment to receive vibration isolation [**and wind-load control**] devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

- A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by [**an agency acceptable to authorities having jurisdiction**].
- B. Hanger-Rod Stiffeners: Install hanger-rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to wind-load forces.
- C. Strength of Support Assemblies: Where not indicated, select sizes of components so strength is adequate to carry static and wind force loads within specified loading limits.

3.3 INSTALLATION OF VIBRATION [**AND WIND-LOAD**] CONTROL DEVICES

- A. Provide vibration [**and wind-load**] control devices for systems and equipment where indicated in Equipment Schedules or Vibration-Control Device Schedules on Drawings, where Specifications indicate they are to be installed on specific equipment and systems, and where required by applicable codes.
- B. Coordinate location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 033000 "Cast-in-Place Concrete."
- C. Installation of vibration isolators [**and wind-load restraints**] must not cause any change of position of equipment, piping, or ductwork resulting in stresses or misalignment.
- D. Comply with requirements in Section 077200 "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.
- E. Equipment Restraints:
 - 1. Install 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 (3.2 mm)**.
 3. Install wind-load-restraint devices using methods approved by **[an agency acceptable to authorities having jurisdiction]** that provides required submittals for component.
- F. Piping Restraints:
1. Comply with requirements in MSS SP-127.
 1. Space lateral supports a maximum of **[40 feet (12 m)]** o.c., and longitudinal supports a maximum of **[80 feet (24 m)]** o.c.
 2. Brace a change of direction longer than **12 feet (3.7 m)**.
- G. Install wind-load-restraint cables so they do not bend across edges of adjacent equipment or building structure.
- H. Install wind-load-restraint devices using methods approved by **[an agency acceptable to authorities having jurisdiction]** that provides required submittals for component.
- I. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.
- J. 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.
- K. 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.
- L. Post-Installed Concrete 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 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-Type Anchor Bolts: 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-Type Anchor Bolts: 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 INSTALLATION OF AIR-SPRING ISOLATORS

A. Independent Isolator Installation:

1. Install automatic leveling valve into each air isolator.
2. Inflate each isolator to the required **[height]** **[and]** **[pressure]**.

3.5 ACCOMMODATION OF DIFFERENTIAL MOTION

- #### A.
- Provide flexible connections in piping systems where they cross structural joints and other point where differential movement may occur. Provide adequate flexibility to accommodate differential movement as determined in accordance with ASCE/SEI 7. Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties" for piping flexible connections.

3.6 INSTALLATION OF VIBRATION ISOLATION EQUIPMENT BASES

- #### A.
- Coordinate location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 033000 "Cast-in-Place Concrete."
- #### B.
- Coordinate dimensions of equipment bases with requirements of isolated equipment specified in this and other Sections. Where dimensions of base are indicated on Drawings, they may require adjustment to accommodate isolated equipment.

3.7 ADJUSTING

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

3.8 FIELD QUALITY CONTROL

- #### A.
- Testing Agency: **[Engage]** a qualified testing agency to perform tests and inspections.
- #### B.
- Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- #### C.
- Perform tests and inspections **[with the assistance of a factory-authorized service representative]**.

D. Tests and Inspections:

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

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

F. Prepare test and inspection reports.

END OF SECTION 230548.13

SECTION 230553 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

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

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product.
- B. Samples: For color, letter style, and graphic representation required for each identification material and device.
- C. Equipment-Label Schedule: Include a listing of all equipment to be labeled with the proposed content for each label.
- D. Valve-numbering scheme.
- E. Valve Schedules: Provide for each piping system. Include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

A. Metal Labels for Equipment:

1. Material and Thickness: [**stainless steel, 0.025-inch (0.64-mm)**] minimum thickness, with predrilled or stamped holes for attachment hardware.
2. Letter and Background Color: As indicated for specific application under Part 3.
3. Minimum Label Size: Length and width vary for required label content, but not less than **2-1/2 by 3/4 inch (64 by 19 mm)**.
4. Minimum Letter Size: **1/4 inch (6.4 mm)** for name of units if viewing distance is less than **24 inches (600 mm)**, **1/2 inch (13 mm)** for viewing distances of up to **72 inches (1830 mm)**, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

- 5. Fasteners: Stainless steel rivets or self-tapping screws.
 - 6. 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), and the Specification Section number and title where equipment is specified.

2.2 WARNING SIGNS AND LABELS

- A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, [**1/8 inch (3.2 mm)**] thick, with predrilled holes for attachment hardware.
- B. Letter and Background Color: As indicated for specific application under Part 3.
- C. Maximum Temperature: Able to withstand temperatures of up to **160 deg F (71 deg C)**.
- D. Minimum Label Size: Length and width vary for required label content, but not less than **2-1/2 by 3/4 inch (64 by 19 mm)**.
- E. Minimum Letter Size: **1/4 inch (6.4 mm)** for name of units if viewing distance is less than **24 inches (600 mm)**, **1/2 inch (13 mm)** for viewing distances of up to **72 inches (1830 mm)**, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
- F. Fasteners: Stainless steel rivets or self-taping screws.
- G. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- H. Arc-Flash Warning Signs: Provide arc-flash warning signs in locations and with content in accordance with requirements of OSHA and NFPA70E [**and other applicable codes and standards**].
- I. Label Content: Include caution and warning information plus emergency notification instructions.

2.3 WARNING TAPE

- A. Material: Vinyl.
- B. Minimum Thickness: **0.005 inch (0.12 mm)**.
- C. Letter, Pattern, and Background Color: As indicated for specific application under Part 3.
- D. Waterproof Adhesive Backing: Suitable for indoor or outdoor use.
- E. Maximum Temperature: **160 deg F (70 deg C)**.
- F. Minimum Width: [**4 inches (100 mm)**].

2.4 PIPE LABELS

- A. General Requirements for Manufactured Pipe Labels: Preprinted, color coded, with lettering indicating service and showing flow direction in accordance with ASME A13.1.
- B. Letter and Background Color: As indicated for specific application under Part 3.
- C. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to **[cover full]** circumference of pipe and to attach to pipe without fasteners or adhesive.
- D. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.
- E. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings. Also include:
 - 1. Pipe size.
 - 2. Flow-Direction Arrows: Include flow-direction arrows on **[main]** distribution piping. Arrows may be either integral with label or applied separately.
 - 3. Lettering Size: **[Size letters in accordance with ASME A13.1 for piping]**.

2.5 DUCT LABELS

- A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, **[1/8 inch (3.2 mm)]** thick, and having predrilled holes for attachment hardware.
- B. Letter and Background Color: As indicated for specific application under Part 3.
- C. Maximum Temperature: Able to withstand temperatures up to **160 deg F (71 deg C)**.
- D. Minimum Label Size: Length and width vary for required label content, but not less than **2-1/2 by 3/4 inch (64 by 19 mm)**.
- E. Minimum Letter Size: **1/4 inch (6.4 mm)** for name of units if viewing distance is less than **24 inches (600 mm)**, **1/2 inch (13 mm)** for viewing distances of up to **72 inches (1830 mm)**, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
- F. Fasteners: Stainless steel rivets or self-tapping screws.
- G. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- H. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings. Also include the following:
 - 1. Duct size.
 - 2. Flow-Direction Arrows: Include flow-direction arrows on **[main]** distribution ducts. Arrows may be either integral with label or may be applied separately.
 - 3. Lettering Size: **[Size letters in accordance with ASME A13.1 for piping]**.

2.6 STENCILS

A. Stencils for Piping:

1. Lettering Size: [Size letters in accordance with ASME A13.1 for piping].
2. Stencil Material: Aluminum, or fiberboard.
3. Stencil Paint: Exterior, gloss, [acrylic enamel] in colors complying with recommendations in ASME A13.1 unless otherwise indicated. Paint may be in pressurized spray-can form.
4. Identification Paint: Exterior, [acrylic enamel]. Paint may be in pressurized spray-can form.
5. Letter and Background Color: As indicated for specific application under Part 3.

B. Stencils for Ducts:

1. Lettering Size: Minimum letter height of 1-1/4 inches (32 mm) for viewing distances of up to 15 ft. (4-1/2 m) and proportionately larger lettering for greater viewing distances.
2. Stencil Material: [Aluminum] [Fiberboard].
3. Stencil Paint: Exterior, gloss, [acrylic enamel]. Paint may be in pressurized spray-can form.
4. Identification Paint: Exterior, [acrylic enamel]. Paint may be in pressurized spray-can form.
5. Letter and Background Color: Color as indicated for specific application under Part 3.

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

1. Lettering Size: Minimum letter height of 1/2 inch (13 mm) for viewing distances of up to 72 inches (1830 mm) and proportionately larger lettering for greater viewing distances.
2. Stencil Material: [Aluminum] [Fiberboard].
3. Stencil Paint: Exterior, gloss, [acrylic enamel]. Paint may be in pressurized spray-can form.
4. Identification Paint: Exterior, [acrylic enamel]. Paint may be in pressurized spray-can form.
5. Letter and Background Color: As indicated for specific application under Part 3.

2.7 VALVE TAGS

A. Description: Stamped or engraved with 1/4-inch (6.4-mm) letters for piping system abbreviation and 1/2-inch (13-mm) numbers.

1. Tag Material: [stainless steel, 0.024-inch (0.61-mm)] minimum thickness, with predrilled or stamped holes for attachment hardware.
2. Fasteners: Brass [link chain].

B. Letter and Background Color: As indicated for specific application under Part 3.

C. Valve Schedules: For each piping system, on 8-1/2-by-11-inch (A4) 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. Include valve-tag schedule in operation and maintenance data.

2.8 WARNING TAGS

- A. Description: Preprinted accident-prevention tags of plasticized card stock [**with matte finish suitable for writing**].
 - 1. Size: [**Approximately 4 by 7 inches (100 by 178 mm)**] <Insert size>.
 - 2. Fasteners: [**Reinforced grommet and wire or string**].
 - 3. Nomenclature: Large-size primary caption, such as "DANGER," "CAUTION," or "DO NOT OPERATE."
 - 4. Letter and Background Color: As indicated for specific application under Part 3.

PART 3 - EXECUTION

3.1 PREPARATION

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

3.2 INSTALLATION, GENERAL REQUIREMENTS

- A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
- B. Coordinate installation of identifying devices with locations of access panels and doors.
- C. Install identifying devices before installing acoustical ceilings and similar concealment.
- D. Locate identifying devices so that they are readily visible from the point of normal approach.

3.3 INSTALLATION OF EQUIPMENT LABELS, WARNING SIGNS, AND LABELS

- A. Permanently fasten labels on each item of mechanical equipment.
- B. Sign and Label Colors:
 - 1. [**White letters on an ANSI Z535.1 safety-blue background**].
- C. Locate equipment labels where accessible and visible.
- D. Arc-Flash Warning Signs: Provide arc-flash warning signs on electrical disconnects and other equipment where arc-flash hazard exists, as indicated on Drawings, and in accordance with requirements of OSHA and NFPA 70E [, **and other applicable codes and standards**].

3.4 INSTALLATION OF WARNING TAPE

- A. Warning Tape Color and Pattern: [**Yellow background with black diagonal stripes**].

- B. Install warning tape on pipes and ducts, with cross-designated walkways providing less than **6 ft. (2 m)** of clearance.
- C. Locate tape so as to be readily visible from the point of normal approach.

3.5 INSTALLATION OF PIPE LABELS

- A. Piping Color Coding: Painting of piping is specified in [Section 099123 "Interior Painting."] [Section 099600 "High-Performance Coatings."]
- B. Install pipe labels showing service and flow direction with permanent adhesive on pipes.
- C. Stenciled Pipe Label Option: Stenciled labels showing service and flow direction may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels, complying with ASME A13.1, [**with painted, color-coded bands or rectangles**] on each piping system.
 - 1. Identification Paint: Use for contrasting background.
 - 2. Stencil Paint: Use for pipe marking.
- D. Pipe-Label Locations: Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:
 - 1. Within **3 ft. (1 m)** of each valve and control device.
 - 2. At access doors, manholes, and similar access points that permit view of concealed piping.
 - 3. Within **3 ft. (1 m)** of equipment items and other points of origination and termination.
 - 4. Spaced at maximum intervals of [**25 ft. (8 m)**] along each run. Reduce intervals to [**10 ft. (3.0 m)**] in areas of congested piping, ductwork, and equipment.
- E. Do not apply plastic pipe labels or plastic tapes directly to bare pipes conveying fluids at temperatures of **125 deg F (52 deg C)** or higher. Where these pipes are to remain uninsulated, use a short section of insulation or use stenciled labels.
- F. Flow-Direction Arrows: Use arrows to indicate direction of flow in pipes, including pipes where flow is allowed in both directions.
- G. Pipe-Label Color Schedule:
 - 1. Chilled-Water Piping: [**White letters on an ANSI Z535.1 safety-green background**].
 - 2. Heating Water Piping: [**White letters on an ANSI Z535.1 safety-green background**].
 - 3. Refrigerant Piping: [**White letters on an ANSI Z535.1 safety-blue background**].
 - 4. Flammable Fluids: [**Black letters on an ANSI Z535.1 safety-yellow background**].
 - 5. Combustible Fluids: [**White letters on an ANSI Z535.1 safety-brown background**].
 - 6. Potable and Other Water: [**White letters on an ANSI Z535.1 safety-green background**].

3.6 INSTALLATION OF DUCT LABELS

- A. Install [**plastic-laminated**] [**self-adhesive**] duct labels showing service and flow direction with permanent adhesive on air ducts.
 - 1. Provide labels in the following color codes:
 - a. For air supply ducts: [**White letters on blue background**].
 - b. For air return ducts: [**White letters on blue background**].
 - c. For exhaust-, outside-, relief-, return-, and mixed-air ducts: [**White letters on blue background**].
- B. Stenciled Duct-Label Option: Stenciled labels showing service and flow direction may be provided instead of plastic-laminated duct labels, at Installer's option.
 - 1. For all air ducts: [**Black letters on white background**].
- C. Locate label near each point where ducts enter into and exit from concealed spaces and at maximum intervals of [**20 ft. (6 m)**] where exposed or are concealed by removable ceiling system.
- D. Stenciled Access Panels and Door Labels, Equipment Labels, and Similar Operational Instructions:
 - 1. [**Black letters on White background**].

3.7 INSTALLATION OF VALVE TAGS

- A. Install tags on valves and control devices in piping systems, except check valves, valves within factory-fabricated equipment units, shutoff valves, and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule in the operating and maintenance manual.
- B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in "Valve-Tag Size and Shape" Subparagraph below.
 - 1. Valve-Tag Size and Shape:
 - a. Chilled Water: [**2 inches (50 mm)**], **square**.
 - b. Refrigerant: [**2 inches (50 mm)**], **square**.
 - c. Hot Water: [**2 inches (50 mm)**], **square**.
 - d. Gas: [**2 inches (50 mm)**], **square**.
 - 2. Valve-Tag Colors:
 - a. For each piping system, use the same lettering and background coloring system on valve tags as used for the Pipe Label Schedule text and background.

3.8 INSTALLATION OF WARNING TAGS

- A. Warning Tag Color: [**Black letters on an ANSI Z535.1 safety-yellow background.**]
- B. Attach warning tags, with proper message, to equipment and other items where [**necessary and requested by engineer**].

END OF SECTION 230553

SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

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. Testing, Adjusting, and Balancing of Air Systems:
 - a. Constant-volume air systems.
 - b. Multizone systems.
 - c. Induction-unit systems.
- 2. Testing, Adjusting, and Balancing of Hydronic Piping Systems:
 - a. Constant-flow hydronic systems.
 - b. Variable-flow hydronic systems.
 - c. Primary-secondary hydronic systems.
- 3. Testing, adjusting, and balancing of fuel oil systems for HVAC.
- 4. Testing, adjusting, and balancing of equipment.
- 5. Procedures for exhaust hoods.
- 6. Sound tests.
- 7. Vibration tests.
- 8. Duct leakage tests verification.
- 9. Pipe leakage tests verification.
- 10. HVAC-control system verification.
- 11. Smoke-control system tests.
- 12. Stair-pressurization system tests.

1.3 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 independent entity meeting qualifications to perform TAB work.
- F. TDH: Total dynamic head.
- G. UFAD: Underfloor air distribution.

1.4 PREINSTALLATION MEETINGS

- A. TAB Conference: Conduct a TAB conference at **[Project site]** after approval of the TAB strategies and procedures plan, to develop a mutual understanding of the details. Provide a minimum of **[14]** days' advance notice of scheduled meeting time and location.
 - 1. Minimum Agenda Items:
 - a. The Contract Documents examination report.
 - b. The TAB plan.
 - c. Needs for coordination and cooperation of trades and subcontractors.
 - d. Proposed procedures for documentation and communication flow.

1.5 INFORMATIONAL SUBMITTALS

- A. Qualification Data: Within **[30]** days of Contractor's Notice to Proceed, submit documentation that the TAB specialist and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.
- B. Contract Documents Examination Report: Within **[30]** 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. System Readiness Checklists: Within **[30]** days of Contractor's Notice to Proceed, submit system readiness checklists, as specified in "Preparation" Article.
- E. Examination Report: Submit a summary report of the examination review required in "Examination" Article.
- F. Certified TAB reports.
- G. Sample report forms.
- H. Instrument calibration reports, to include the following:
 - 1. Instrument type and make.
 - 2. Serial number.
 - 3. Application.
 - 4. Dates of use.
 - 5. Dates of calibration.

1.6 QUALITY ASSURANCE

- A. TAB Specialists Qualifications, Certified by AABC:
 - 1. TAB Field Supervisor: Employee of the TAB specialist and certified by AABC.
 - 2. TAB Technician: Employee of the TAB specialist and certified by AABC.
- B. TAB Specialists Qualifications, Certified by [NEBB] [or] [TABB]:
 - 1. TAB Field Supervisor: Employee of the TAB specialist and certified by [NEBB] [or] [TABB].
 - 2. TAB Technician: Employee of the TAB specialist and certified by [NEBB] [or] [TABB].
- C. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."
- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.7.2.3 - "System Balancing."
- E. Code and AHJ Compliance: TAB is required to comply with governing codes and requirements of authorities having jurisdiction.

1.7 FIELD CONDITIONS

- A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.
- B. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 TAB SPECIALISTS

- A. Subject to compliance with requirements, **[available TAB specialists that may be engaged]**.

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 installed systems for balancing devices, such as test ports, gauge cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.
- C. Examine the approved submittals for HVAC systems and equipment.
- 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 HVAC to verify that they are properly separated from adjacent areas and sealed.
- F. Examine equipment performance data, including fan and pump curves.
 - 1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
 - 2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.
- G. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.
- H. Examine test reports specified in individual system and equipment Sections.
- I. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.
- J. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.
- K. Examine temporary and permanent strainers. Verify that temporary strainer screens used during system cleaning and flushing have been removed and permanent strainer baskets are installed and clean.
- L. Examine control valves for proper installation for their intended function of isolating, throttling, diverting, or mixing fluid flows.
- M. Examine heat-transfer coils for correct piping connections and for clean and straight fins.
- N. Examine system pumps to ensure absence of entrained air in the suction piping.
- O. Examine operating safety interlocks and controls on HVAC equipment.
- P. Examine control dampers for proper installation for their intended function of isolating, throttling, diverting, or mixing air flows.

- Q. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.3 PREPARATION

- A. Prepare a TAB plan that includes the following:
1. Equipment and systems to be tested.
 2. Strategies and step-by-step procedures for balancing the systems.
 3. Instrumentation to be used.
 4. Sample forms with specific identification for all equipment.
- B. Perform system-readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:
1. Airside:
 - a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.
 - b. Duct systems are complete with terminals installed.
 - c. Volume, smoke, and fire dampers are open and functional.
 - d. Clean filters are installed.
 - e. Fans are operating, free of vibration, and rotating in correct direction.
 - f. Variable-frequency controllers' startup is complete and safeties are verified.
 - g. Automatic temperature-control systems are operational.
 - h. Ceilings are installed.
 - i. Windows and doors are installed.
 - j. Suitable access to balancing devices and equipment is provided.
 2. Hydronics:
 - a. Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.
 - b. Piping is complete with terminals installed.
 - c. Water treatment is complete.
 - d. Systems are flushed, filled, and air purged.
 - e. Strainers are pulled and cleaned.
 - f. Control valves are functioning in accordance with the sequence of operation.
 - g. Shutoff and balance valves have been verified to be 100 percent open.
 - h. Pumps are started and proper rotation is verified.
 - i. Pump gauge connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.
 - j. Variable-frequency controllers' startup is complete and safeties are verified.
 - k. Suitable access to balancing devices and equipment is provided.

3.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

- A. Perform testing and balancing procedures on each system in accordance with the procedures contained in [AABC's "National Standards for Total System Balance"] [NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems"] and in this Section.
- B. Cut insulation, ducts, pipes, and equipment casings for installation of test probes to the minimum extent necessary for TAB procedures.
 - 1. After testing and balancing, install test ports and duct access doors that comply with requirements in Section 233300 "Air Duct Accessories."
 - 2. Where holes for probes are required in piping or hydronic equipment, install pressure and temperature test plugs to seal systems.
 - 3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish in accordance with Section 230713 "Duct Insulation," Section 230716 "HVAC Equipment Insulation," and Section 230719 "HVAC Piping Insulation."
- C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.
- D. Take and report testing and balancing measurements in [inch-pound (IP)] [and] [metric (SI)] units.

3.5 TESTING, ADJUSTING, AND BALANCING OF HVAC EQUIPMENT

- A. Test, adjust, and balance HVAC equipment indicated on Drawings, including, but not limited to, the following:
 - 1. Motors.
 - 2. Pumps.
 - 3. Fans and ventilators.
 - 4. Air curtains.
 - 5. Terminal units.
 - 6. Commercial kitchen hoods.
 - 7. Boilers.
 - 8. Heat exchangers.
 - 9. Condensing units.
 - 10. Water chillers.
 - 11. Energy-recovery units.
 - 12. Air-handling units.
 - 13. Heating and ventilating units.
 - 14. Heating-only makeup air units.
 - 15. Dedicated outdoor-air units.
 - 16. Split-system air conditioners.
 - 17. Variable-refrigerant-flow systems.
 - 18. Heat pumps.
 - 19. Coils.

- 20. Fan coil units.
- 21. Unit ventilators.

3.6 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' Record drawings duct layouts.
- C. For variable-air-volume systems, develop a plan to simulate diversity.
- D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.
- E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.
- F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
- G. Verify that motor starters are equipped with properly sized thermal protection.
- H. Check dampers for proper position to achieve desired airflow path.
- I. Check for airflow blockages.
- J. Check condensate drains for proper connections and functioning.
- K. Check for proper sealing of air-handling-unit components.

3.7 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

- A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
 - 1. Measure total airflow.
 - a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
 - b. Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.
 - c. Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.

2. Measure fan static pressures as follows:
 - a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.
 - c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report artificial loading of filters at the time static pressures are measured.
 3. Review Contractor-prepared shop drawings and Record drawings to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
 4. Obtain approval from [Architect] [Owner] [Construction Manager] [Commissioning Authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
 5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
- B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.
1. Measure airflow of submain and branch ducts.
 2. Adjust submain and branch duct volume dampers for specified airflow.
 3. Re-measure each submain and branch duct after all have been adjusted.
- C. Adjust air inlets and outlets for each space to indicated airflows.
1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
 2. Measure inlets and outlets airflow.
 3. Adjust each inlet and outlet for specified airflow.
 4. Re-measure each inlet and outlet after they have been adjusted.
- D. Verify final system conditions.
1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to design if necessary.
 2. Re-measure and confirm that total airflow is within design.
 3. Re-measure all final fan operating data, speed, volts, amps, and static profile.
 4. Mark all final settings.
 5. Test system in economizer mode. Verify proper operation and adjust if necessary.
 6. Measure and record all operating data.
 7. Record final fan-performance data.

3.8 PROCEDURES FOR MULTIZONE SYSTEMS

- A. Position the unit's automatic zone dampers for maximum flow through the cooling coil.
- B. The procedures for multizone systems will utilize the zone balancing dampers to achieve the indicated airflow within the zone.
- C. After balancing, place the unit's automatic zone dampers for maximum heating flow. Retest zone airflows and record any variances.
- D. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
 - 1. Measure total airflow.
 - a. Set outside-air, return-air and relief-air dampers for proper position that simulates minimum outdoor air conditions.
 - b. Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.
 - c. Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
 - 2. Measure fan static pressures as follows:
 - a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.
 - c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report artificial loading of filters at the time static pressures are measured.
 - 3. Review Record drawings to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
 - 4. Obtain approval from **[Architect]** **[Owner]** **[Construction Manager]** **[Commissioning Authority]** for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
 - 5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
- E. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.
 - 1. Measure airflow of submain and branch ducts.
 - 2. Adjust submain and branch duct volume dampers for specified airflow.
 - 3. Re-measure each submain and branch duct after all have been adjusted.

- F. Adjust air inlets and outlets for each space to indicated airflows.
 - 1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
 - 2. Measure inlet and outlet airflow.
 - 3. Adjust each inlet and outlet for specified airflow.
 - 4. Re-measure each inlet and outlet after they have been adjusted.
- G. Verify final system conditions.
 - 1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
 - 2. Re-measure and confirm that total airflow is within design.
 - 3. Re-measure all final fan operating data, speed, volts, amps, and static profile.
 - 4. Mark all final settings.
 - 5. Test system in economizer mode. Verify proper operation and adjust if necessary.
 - 6. Measure and record all operating data.
 - 7. Record final fan-performance data.

3.9 PROCEDURES FOR INDUCTION-UNIT SYSTEMS

- A. Balance primary-air risers by measuring static pressure at the nozzles of the top and bottom units of each riser, to determine which risers must be throttled. Adjust risers to indicated airflow within specified tolerances.
- B. Adjust each induction unit.
- C. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
 - 1. Measure total airflow.
 - a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
 - b. Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.
 - c. Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
 - 2. Measure fan static pressures as follows:
 - a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.
 - c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report artificial loading of filters at the time static pressures are measured.
 - 3. Review Record drawings to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

4. Obtain approval from [Architect] [Owner] [Construction Manager] [Commissioning Authority] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
 5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
- D. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.
1. Measure airflow of submain and branch ducts.
 2. Adjust submain and branch duct volume dampers for specified airflow.
 3. Re-measure each submain and branch duct after all have been adjusted.
- E. Balance airflow to each induction unit by measuring the nozzle pressure and comparing it to the manufacturer's published data for nozzle pressure versus cfm. Adjust the unit's inlet damper to achieve the required nozzle pressure for design cfm.
- F. Verify final system conditions.
1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
 2. Re-measure and confirm that total airflow is within design.
 3. Re-measure all final fan operating data, speeds, volts, amps, and static profile.
 4. Mark all final settings.
 5. Test system in economizer mode. Verify proper operation and adjust if necessary.
 6. Measure and record all operating data.
 7. Record final fan-performance data.

3.10 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

- A. Prepare test reports for pumps, coils, and other equipment. Obtain approved submittals and manufacturer-recommended testing procedures. Crosscheck the summation of required coil and equipment flow rates with pump design flow rate.
- B. Prepare schematic diagrams of systems' Record drawings piping layouts.
- C. In addition to requirements in "Preparation" Article, prepare hydronic systems for testing and balancing as follows:
1. Check expansion tank for proper setting.
 2. Check highest vent for adequate pressure.
 3. Check flow-control valves for proper position.
 4. Locate start-stop and disconnect switches, electrical interlocks, and motor controllers.
 5. Verify that motor controllers are equipped with properly sized thermal protection.
 6. Check that air has been purged from the system.

- D. Measure and record upstream and downstream pressure of each piece of equipment.
- E. Measure and record upstream and downstream pressure of pressure-reducing valves.
- F. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.
 - 1. Check settings and operation of each safety valve. Record settings.

3.11 PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

- A. Adjust pumps to deliver total design flow.
 - 1. Measure total water flow.
 - a. Position valves for full flow through coils.
 - b. Measure flow by main flow meter, if installed.
 - c. If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.
 - 2. Measure pump TDH as follows:
 - a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
 - b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
 - c. Convert pressure to head and correct for differences in gauge heights.
 - d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
 - e. With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.
 - 3. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.
- B. Adjust flow-measuring devices installed in mains and branches to design water flows.
 - 1. Measure flow in main and branch pipes.
 - 2. Adjust main and branch balance valves for design flow.
 - 3. Re-measure each main and branch after all have been adjusted.
- C. Adjust flow-measuring devices installed at terminals for each space to design water flows.
 - 1. Measure flow at terminals.
 - 2. Adjust each terminal to design flow.
 - 3. Re-measure each terminal after it is adjusted.

4. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
 5. Perform temperature tests after flows have been balanced.
- D. For systems with pressure-independent valves at terminals:
1. Measure differential pressure and verify that it is within manufacturer's specified range.
 2. Perform temperature tests after flows have been verified.
- E. For systems without pressure-independent valves or flow-measuring devices at terminals:
1. Measure and balance coils by either coil pressure drop or temperature method.
 2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.
- F. Verify final system conditions as follows:
1. Re-measure and confirm that total water flow is within design.
 2. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.
 3. Mark final settings.
- G. Verify that memory stops have been set.

3.12 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

- A. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals, and proceed as specified above for hydronic systems.
- B. Adjust the variable-flow hydronic system as follows:
1. Verify that the pressure-differential sensor(s) is located as indicated.
 2. Determine whether there is diversity in the system.
- C. For systems with no flow diversity:
1. Adjust pumps to deliver total design flow.
 - a. Measure total water flow.
 - 1) Position valves for full flow through coils.
 - 2) Measure flow by main flow meter, if installed.
 - 3) If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.
 - b. Measure pump TDH as follows:
 - 1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.

- 2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
 - 3) Convert pressure to head and correct for differences in gauge heights.
 - 4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
 - 5) With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.
 - c. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.
2. Adjust flow-measuring devices installed in mains and branches to design water flows.
 - a. Measure flow in main and branch pipes.
 - b. Adjust main and branch balance valves for design flow.
 - c. Re-measure each main and branch after all have been adjusted.
3. Adjust flow-measuring devices installed at terminals for each space to design water flows.
 - a. Measure flow at terminals.
 - b. Adjust each terminal to design flow.
 - c. Re-measure each terminal after it is adjusted.
 - d. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
 - e. Perform temperature tests after flows have been balanced.
4. For systems with pressure-independent valves at terminals:
 - a. Measure differential pressure and verify that it is within manufacturer's specified range.
 - b. Perform temperature tests after flows have been verified.
5. For systems without pressure-independent valves or flow-measuring devices at terminals:
 - a. Measure and balance coils by either coil pressure drop or temperature method.
 - b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.
6. Prior to verifying final system conditions, determine the system pressure-differential set point(s).
7. If the pump discharge valve was used to set total system flow with variable-frequency controller at 50 Hz, at completion, open discharge valve 100 percent, and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.
8. Mark final settings and verify that all memory stops have been set.
9. Verify final system conditions as follows:

- a. Re-measure and confirm that total flow is within design.
 - b. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.
 - c. Mark final settings.
- D. For systems with flow diversity:
 1. Determine diversity factor.
 2. Simulate system diversity by closing required number of control valves, as approved by Architect.
 3. Adjust pumps to deliver total design flow.
 - a. Measure total water flow.
 - 1) Position valves for full flow through coils.
 - 2) Measure flow by main flow meter, if installed.
 - 3) If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.
 - b. Measure pump TDH as follows:
 - 1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
 - 2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
 - 3) Convert pressure to head and correct for differences in gauge heights.
 - 4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
 - 5) With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.
 - c. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.
 4. Adjust flow-measuring devices installed in mains and branches to design water flows.
 - a. Measure flow in main and branch pipes.
 - b. Adjust main and branch balance valves for design flow.
 - c. Re-measure each main and branch after all have been adjusted.
 5. Adjust flow-measuring devices installed at terminals for each space to design water flows.
 - a. Measure flow at terminals.
 - b. Adjust each terminal to design flow.
 - c. Re-measure each terminal after it is adjusted.

- d. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
 - e. Perform temperature tests after flows have been balanced.
6. For systems with pressure-independent valves at terminals:
 - a. Measure differential pressure, and verify that it is within manufacturer's specified range.
 - b. Perform temperature tests after flows have been verified.
7. For systems without pressure-independent valves or flow-measuring devices at terminals:
 - a. Measure and balance coils by either coil pressure drop or temperature method.
 - b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.
8. Open control valves that were shut. Close a sufficient number of control valves that were previously open to maintain diversity, and balance terminals that were just opened.
9. Prior to verifying final system conditions, determine system pressure-differential set point(s).
10. If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion, open discharge valve 100 percent, and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.
11. Mark final settings and verify that memory stops have been set.
12. Verify final system conditions as follows:
 - a. Re-measure and confirm that total water flow is within design.
 - b. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.
 - c. Mark final settings.

3.13 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

- A. Balance the primary circuit flow first.
- B. Balance the secondary circuits after the primary circuits are complete.
- C. Adjust pumps to deliver total design flow.
 1. Measure total water flow.
 - a. Position valves for full flow through coils.
 - b. Measure flow by main flow meter, if installed.
 - c. If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.

2. Measure pump TDH as follows:
 - a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
 - b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
 - c. Convert pressure to head and correct for differences in gauge heights.
 - d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
 - e. With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.
 3. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.
- D. Adjust flow-measuring devices installed in mains and branches to design water flows.
1. Measure flow in main and branch pipes.
 2. Adjust main and branch balance valves for design flow.
 3. Re-measure each main and branch after all have been adjusted.
- E. Adjust flow-measuring devices installed at terminals for each space to design water flows.
1. Measure flow at terminals.
 2. Adjust each terminal to design flow.
 3. Re-measure each terminal after it is adjusted.
 4. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
 5. Perform temperature tests after flows have been balanced.
- F. For systems with pressure-independent valves at terminals:
1. Measure differential pressure and verify that it is within manufacturer's specified range.
 2. Perform temperature tests after flows have been verified.
- G. For systems without pressure-independent valves or flow-measuring devices at terminals:
1. Measure and balance coils by either coil pressure drop or temperature method.
 2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.
- H. Verify final system conditions as follows:
1. Re-measure and confirm that total water flow is within design.
 2. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.
 3. Mark final settings.
- I. Verify that memory stops have been set.

3.14 PROCEDURES FOR WATER-TO-WATER HEAT EXCHANGERS

- A. Adjust and record water flow to within specified tolerances.
- B. Measure and record inlet and outlet water temperatures.
- C. Measure and record pressure drop.
- D. Check and record settings and operation of safety and relief valves.

3.15 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. Phase and hertz.
 - 5. Nameplate and measured voltage, each phase.
 - 6. Nameplate and measured amperage, each phase.
 - 7. Starter size and thermal-protection-element rating.
 - 8. Service factor and frame size.
- B. Motors Driven by Variable-Frequency Controllers: Test manual bypass of controller to prove proper operation.

3.16 PROCEDURES FOR WATER CHILLERS

- A. Air-Cooled Chillers: Balance water flow through each evaporator to within specified tolerances of indicated flow, with all pumps operating. With only one chiller operating in a multiple-chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:
 - 1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
 - 2. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
 - 3. Power factor if factory-installed instrumentation is furnished for measuring kilowatts.
 - 4. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
 - 5. Capacity: Calculate in [tons] [kilowatts] of cooling.
 - 6. Efficiency: Calculate operating efficiency for comparison to submitted equipment.
 - 7. Verify condenser-fan rotation and record fan and motor data, including number of fans and entering- and leaving-air temperatures.

3.17 PROCEDURES FOR AIR-COOLED CONDENSING UNITS

- A. Verify proper rotation of fan(s).
- B. Measure and record entering- and leaving-air temperatures.
- C. Measure and record entering and leaving refrigerant pressures.
- D. Measure and record operating data of compressor(s), fan(s), and motors.

3.18 PROCEDURES FOR BOILERS

A. Hydronic Boilers:

- 1. Measure and record entering- and leaving-water temperatures.
- 2. Measure and record water flow.
- 3. Measure and record pressure drop.
- 4. **[Measure and]** Record relief valve(s) pressure setting.
- 5. Capacity: Calculate in **Btu/h (kW)** of heating output.
- 6. Fuel Consumption: If boiler fuel supply is equipped with flow meter, measure and record consumption.
- 7. Efficiency: Calculate operating efficiency for comparison to submitted equipment.
- 8. Fan, motor, and motor controller operating data.

B. Boilers with Flue Gas Economizers:

- 1. Measure and record entering- and leaving-water temperature.
- 2. Measure and record water flow rate.
- 3. Measure and record water pressure drop.
- 4. Heat Recovered: Calculate in **Btu/h (kW)** of waste heat recovered.

3.19 PROCEDURES FOR HEAT-TRANSFER COILS

A. Measure, adjust, and record the following data for each hydronic 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. Air pressure drop.

5. Voltage and amperage input of each phase at full load.
6. Calculated kilowatt at full load.
7. Fuse or circuit-breaker rating for overload protection.

C. 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. Entering and leaving refrigerant pressure and temperatures.

3.20 PROCEDURES FOR EXHAUST HOODS

- A. Room Pressure: Measure and record room pressure with respect to atmosphere and adjacent space with hoods in room initially not operating and then with hoods operating.
- B. Makeup Air: Systems supplying source of makeup air to hoods shall be in operation during testing and balancing of exhaust hoods.
1. Measure and record temperature of makeup air entering hood. If hood makeup air is from multiple sources having different temperatures, measure and record the airflow and temperatures of each source and calculate the weighted average temperature.
 2. Use simulated smoke to observe supply air-distribution air patterns in vicinity of hoods. Consult with hood manufacturer and report conditions that have a detrimental effect on intended capture, containment, and other attributes effecting proper operation.
- C. Rooms with Multiple Hoods: Test each hood separately, one at a time, and repeat tests with all hoods intended to operate simultaneously by design.
- D. Kitchen Hoods:
1. Type 1: Measure and record pressure drop and face velocity of hood filters and slots in accordance with hood manufacturer's instructions. Consult hood manufacturer to determine hood airflow using recorded information.
 2. Type 2: Measure and record airflow by duct traverse.
 3. Capture and Containment: Check each hood for proper capture and containment using a smoke-emitting device. Observe and report performance. Make adjustments to achieve optimum results.
- E. AHJ Tests: Conduct additional tests required by authorities having jurisdiction.

3.21 SOUND TESTS

- A. After systems are balanced and Substantial Completion, measure and record sound levels at [10] [15] locations as designated by the Architect.

B. Instrumentation:

1. The sound-testing meter shall be a portable, general-purpose testing meter consisting of a microphone, processing unit, and readout.
2. The sound-testing meter shall be capable of showing fluctuations at minimum and maximum levels, and measuring the equivalent continuous sound pressure level (L_{eq}).
3. The sound-testing meter must be capable of using one-third octave band filters to measure mid-frequencies from 31.5 Hz to 8000 Hz.
4. The accuracy of the sound-testing meter shall be plus or minus one decibel.

C. Test Procedures:

1. Perform test at quietest background noise period. Note cause of unpreventable sound that affects test outcome.
2. Equipment should be operating at design values.
3. Calibrate the sound-testing meter prior to taking measurements.
4. Use a microphone suitable for the type of noise levels measured that is compatible with meter. Provide a windshield for outside or in-duct measurements.
5. Record a set of background measurements in dBA and sound pressure levels in the eight unweighted octave bands [**63 Hz to 8000 Hz (NC)**] with the equipment off.
6. Take sound readings in dBA and sound pressure levels in the eight unweighted octave bands [**63 Hz to 8000 Hz (NC)**] with the equipment operating.
7. Take readings no closer than **36 inches (900 mm)** from a wall or from the operating equipment and approximately **60 inches (1500 mm)** from the floor, with the meter held or mounted on a tripod.
8. For outdoor measurements, move sound-testing meter slowly and scan area that has the most exposure to noise source being tested. Use A-weighted scale for this type of reading.

D. Reporting:

1. Report shall record the following:
 - a. Location.
 - b. System tested.
 - c. dBA reading.
 - d. Sound pressure level in each octave band with equipment on and off.
2. Plot sound pressure levels on [**Noise Criteria (NC)**] [**or**] [**Room Criteria (RC)**] worksheet with equipment on and off.

3.22 VIBRATION TESTS

- A. After systems are balanced and Substantially Completion, measure and record vibration levels on equipment having motor horsepower equal to or greater than [**10**].

B. Instrumentation:

1. Use portable, battery-operated, and microprocessor-controlled vibration meter with or without a built-in printer.
2. The meter shall automatically identify engineering units, filter bandwidth, amplitude, and frequency scale values.
3. The meter shall be able to measure machine vibration displacement in mils of deflection, velocity in inches per second, and acceleration in inches per second squared.
4. Verify calibration date is current for vibration meter before taking readings.

C. Test Procedures:

1. To ensure accurate readings, verify that accelerometer has a clean, flat surface and is mounted properly.
2. With the unit running, set up vibration meter in a safe, secure location. Connect transducer to meter with proper cables. Hold magnetic tip of transducer on top of the bearing, and measure unit in mils of deflection. Record measurement, then move transducer to the side of the bearing and record in mils of deflection. Record an axial reading in mils of deflection by holding nonmagnetic, pointed transducer tip on end of shaft.
3. Change vibration meter to velocity (inches per second) measurements. Repeat and record above measurements.
4. Record CPM or rpm.
5. Read each bearing on motor, fan, and pump as required. Track and record vibration levels from rotating component through casing to base.

D. Reporting:

1. Report shall record location and the system tested.
2. Include horizontal-vertical-axial measurements for tests.
3. Verify that vibration limits follow Specifications, or, if not specified, follow the General Machinery Vibration Severity Chart or Vibration Acceleration General Severity Chart from AABC's "National Standards for Total System Balance." Acceptable levels of vibration are normally "smooth" to "good."
4. Include in General Machinery Vibration Severity Chart, with conditions plotted.

3.23 DUCT LEAKAGE TESTS

- A. Witness the duct leakage testing performed by Installer.
- B. Verify that proper test methods are used and that leakage rates are within specified limits.
- C. Report deficiencies observed.

3.24 PIPE LEAKAGE TESTS

- A. Witness the pipe pressure testing performed by Installer.
- B. Verify that proper test methods are used and that leakage rates are within specified limits.
- C. Report deficiencies observed.

3.25 HVAC CONTROLS VERIFICATION

- A. In conjunction with system balancing, perform the following:
 - 1. Verify HVAC control system is operating within the design limitations.
 - 2. Confirm that the sequences of operation are in compliance with Contract Documents.
 - 3. Verify that controllers are calibrated and function as intended.
 - 4. Verify that controller set points are as indicated.
 - 5. Verify the operation of lockout or interlock systems.
 - 6. Verify the operation of valve and damper actuators.
 - 7. Verify that controlled devices are properly installed and connected to correct controller.
 - 8. Verify that controlled devices travel freely and are in position indicated by controller: open, closed, or modulating.
 - 9. Verify location and installation of sensors to ensure that they sense only intended temperature, humidity, or pressure.
- B. Reporting: Include a summary of verifications performed, remaining deficiencies, and variations from indicated conditions.

3.26 PROCEDURES FOR STAIR-PRESSURIZATION SYSTEMS

- A. Before testing, observe each pressurized stair enclosure to verify construction is complete. Verify the following:
 - 1. Walls and ceiling are free of unintended openings and are capable of achieving a pressure boundary.
 - 2. Firestopping and sealants are installed.
 - 3. Doors, door closers, and door gaskets are installed and adjusted.
 - 4. If applicable, window installation is complete.
 - 5. Stair-pressurization fans and associated controls are installed and functioning properly.
 - 6. Stair-pressurization duct distribution and air outlets are installed.
 - 7. Life-safety dampers (smoke or combination fire and smoke) are installed and functioning properly.
- B. Measure and record barometric pressure, wind speed and direction, outdoor-air temperature, and relative humidity on each test day.
- C. Test each stair enclosure as a single system. If multiple fans serve a single stair enclosure, operate fans as intended by the design.

D. Initial Air Balance:

1. Open doors to floors where indicated by design and measure, adjust, and record the airflow of each:
 - a. Stair-pressurization fan. For ducted systems, measure fan airflow by duct Pitot-tube traverse unless duct distribution does not permit accurate readings.
 - b. Air outlet supplying stair enclosure.
 - c. Adjust enclosure total airflow to achieve design pressurization.
 - d. Adjust method of stair enclosure pressure relief to prevent overpressurization.

E. Pressurization Test and Adjustments:

1. After air balancing is complete, perform stair enclosure pressurization tests.
2. Establish a consistent procedure for recording data throughout entire test.
3. Use stair side of doors as pressure reference point.
 - a. Positive Pressure: Floor side of door higher than stair side.
 - b. Negative Pressure: Floor side of door lower than stair side.
4. With HVAC systems and stair-pressurization systems off, measure and record the following:
 - a. Pressure difference across each stair enclosure door, with all doors in the stair enclosure closed.
 - b. Force necessary to open each door, using a spring-type scale.
 - c. Adjustment needed to achieve design pressurization of enclosure total airflow.
 - d. Adjustment needed to method of stair enclosure pressure relief, to prevent overpressurization.
5. With HVAC systems operating in normal mode and stair-pressurization systems off, measure and record the following:
 - a. Pressure difference across each stair enclosure door, with all doors in the stair enclosure closed.
 - b. Force necessary to open each door, using a spring-type scale.
 - c. Adjustment needed to achieve design pressurization of enclosure total airflow.
 - d. Adjustment needed to method of stair enclosure pressure relief, to prevent overpressurization.
6. With HVAC systems and stair-pressurization system operating simultaneously, perform the following:
 - a. Place HVAC systems in normal operating mode, including equipment not used to implement smoke control, such as air-handling units, exhaust fans, and similar equipment.
 - b. Measure and record pressure difference across each stair enclosure door, with all doors in stair enclosure closed.
 - c. Use a spring scale to measure and record the force needed to open all stair enclosure doors.

- d. Adjust enclosure total airflow to achieve design pressurization.
- e. Adjust method of stair enclosure pressure relief to prevent overpressurization.
- f. Additional Tests for Designs with Open Doors:
 - 1) With exit door to outdoors in open position, measure and record pressure difference across each of the remaining closed stair enclosure doors.
 - 2) Open additional doors (up to the number indicated by design) one at a time, and measure and record pressure difference across each remaining closed stair enclosure door after the opening of each additional door.
 - 3) For each different test condition, measure and record the direction and velocity through each of the open doors by a traverse of every [1 sq. ft. (0.093 sq. m)] grid of door opening.
 - 4) For each different test condition, calculate average of door velocity measurements. Compare average velocity to design and governing code requirements.
 - 5) Adjust enclosure total airflow to achieve design pressurization.
 - 6) Adjust method of stair enclosure pressure relief to prevent overpressurization.
- 7. Repeat pressurization tests with the smoke-control systems and HVAC systems operating.
- 8. Criteria for Acceptance:
 - a. Compliance with design requirements.
 - b. Compliance with code requirements.
 - c. Compliance with additional requirements required by authorities having jurisdiction.
- F. Operational Tests:
 - 1. Check proper activation of stair-pressurization system(s) in response to all means of activation, both automatic and manual.
 - 2. Verify that each initiating occurrence produces the proper system response under each of the following modes of operation:
 - a. Normal.
 - b. Alarm.
 - c. Manual override.
 - d. Return to normal.
 - 3. Verify smoke detector at pressurization fan de-energizes fan and closes isolation damper when smoke detector is activated and in alarm.
 - 4. If standby power is provided for pressurization systems, test to verify pressurization systems operate while on both normal and standby power.
 - 5. Check operation in accordance with design indicated.
- G. AHJ Tests: Conduct additional tests required by authorities having jurisdiction.
- H. Report: Prepare and submit a complete report of observations, measurements, and deficiencies. Include names and contact information of individuals conducting tests and of individuals witnessing tests.

3.27 PROCEDURES FOR SMOKE-CONTROL SYSTEM TESTING

- A. Before testing smoke-control systems, review design documents to understand operating requirements and design intent:
 - 1. Review boundaries of each smoke zone.
 - 2. Review location, size, and operating characteristics of equipment, such as smoke and fire smoke dampers.
 - 3. Review sequence of operation, operating status of equipment, and position of smoke and fire dampers for each smoke zone alarm condition.
 - 4. Review location and type of alarm detection used to initiate smoke control for each smoke zone.
 - 5. Review other smoke-control system attributes not listed but required for code compliance and acceptance by authorities having jurisdiction.
- B. Before testing smoke-control systems, verify that construction is complete and verify the integrity of each smoke-control zone boundary.
 - 1. Verify that windows, doors, walls, ceilings, and floors (six-sided boundary) are closed and that applicable safing, gasket, and firestops and sealants are installed.
 - 2. Report deficiencies and postpone testing until after the reported deficiencies are corrected.
- C. Measure and record barometric pressure, wind speed and direction, outdoor-air temperature, and relative humidity on each test day.
- D. Measure, adjust, and record airflow of each smoke-control system, with all fans that are a part of system operating as intended by the design.
 - 1. Measure, adjust, and record the airflow of each fan. For ducted systems, measure fan airflow by duct Pitot-tube traverse.
 - 2. Measure, adjust, and record the airflow of each exhaust inlet and supply outlet.
 - 3. Measure, adjust, and record airflow in main and branch ducts.
- E. Smoke Control by Pressurization: After air balancing is complete, perform the following pressurization testing for each smoke-control zone in the system designed for isolation by using pressurization boundaries:
 - 1. Verify the boundaries of each smoke-control zone.
 - 2. With the HVAC systems in their normal mode of operation and smoke control not operating, measure and record the pressure difference across each smoke-control zone. Make measurements after closing doors that separate the zones. Make one measurement across each door. Clearly indicate the high- and low-pressure side of each door.
 - 3. With the system operating in the smoke-control mode and with each separate zone in the smoke-control system activated, perform the following:
 - a. Measure and record the pressure difference across each door that separates the smoke zone from adjacent zones.
 - 1) Make measurements with doors that separate the smoke zone from the other zones closed.

- 2) Clearly indicate the high- and low-pressure side of the door.
 - 3) Doors that have a tendency to open slightly due to the pressure difference should have one pressure measurement made while held closed and another measurement made with the door open.
 - b. Continue to activate each separate smoke zone within each smoke-control system, and make pressure-difference measurements.
 - c. After testing a smoke zone's smoke-control system, deactivate the HVAC systems involved and return them to their normal operating mode before activating another zone's smoke-control system.
 - d. Verify that controls necessary to prevent excessive pressure differences are functional and operating within design set points and limits.
- F. Smoke-Control Systems for Atriums and Other Large-Volume Spaces: After air balancing is complete, perform the following testing for each smoke-control system serving atriums and other large-volume spaces:
 1. Verify and document the boundaries served by each smoke-control system.
 2. Identify and document closed doors, open doors, and other boundary openings to be left open to adjacent areas and that are to be protected by airflow alone.
 3. With the HVAC systems in their normal mode of operation and smoke-control systems not operating, measure and record the following:
 - a. Pressure difference across each door that separates the smoke-zone from adjacent zones.
 - b. Velocity for each point in traverse across each boundary opening:
 - 1) Clearly indicate the direction of flow.
 - 2) Measure velocity across opening on [12-inch (300-mm)] centers using a vane anemometer.
 - 3) Calculate and report airflow.
 4. With system operating in the smoke-control mode, measure and record the following:
 - a. Pressure difference across each door that separates the smoke-zone from adjacent zones.
 - b. Velocity for each point in traverse across each opening:
 - 1) Clearly indicate the direction of flow.
 - 2) Measure velocity across opening on [12-inch (300-mm)] centers using a vane anemometer.
 - 3) Calculate and report airflow.
 5. Verify system operation and make adjustments to achieve design pressure differences and air velocities within design set points and upper operating limits.

G. Operational Tests:

1. Check the proper activation of each zone of each smoke-control system in response to all means of activation, both automatic and manual.
2. Check automatic activation in response to fire alarm signals received from the building's fire alarm system. Initiate a separate alarm for each means of activation to ensure that the proper operation of the correct zone of each smoke-control system occurs.
3. Check and record proper operation of fans, dampers, and related equipment for each separate zone of each smoke-control system:
 - a. Zone in which a smoke-control system automatically activates.
 - b. Type of signal that activates smoke-control system, such as sprinkler flow or smoke detector.
 - c. Smoke zone(s) where maximum mechanical exhaust to the outside is implemented and no supply air is provided.
 - d. Positive-pressure smoke-control zone(s) where maximum air supply is implemented and no exhaust to the outside is provided.
 - e. Fan(s) "ON" as required to implement the smoke-control system. Multiple- or variable-speed fans should be further noted to verify that the intended control configuration is achieved.
 - f. Fan(s) "OFF" as required to implement the smoke-control system.
 - g. Damper(s) "OPEN" or at an adjustable position where maximum airflow must be achieved.
 - h. Damper(s) "CLOSED" where no airflow should take place.
 - i. Auxiliary functions to achieve the smoke-control system configuration, such as changes or override of normal operating pressure and temperature-control set points.
 - j. If standby power is provided for the smoke-control system, test to verify that the system functions while operating under both normal and standby power.
 - k. Check operation in accordance with design indicated.

H. AHJ Tests: Conduct additional tests required by authorities having jurisdiction. [**Unless required by authorities having jurisdiction, perform testing without the use of smoke or products that simulate smoke.**]

I. Report: Prepare and submit a complete report of observations, measurements, and deficiencies. Include names and contact information of individuals conducting tests and of individuals witnessing tests.

3.28 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

A. Perform a preconstruction inspection of existing equipment that is to remain and be reused.

1. Measure and record the operating speed, airflow, and static pressure of each fan and equipment with fan(s).
2. Measure and record flows, temperatures, and pressures of each piece of equipment in each hydronic system. Compare the values to design or nameplate information, where information is available.

3. Measure motor voltage and amperage. Compare the values to motor nameplate information.
 4. Check the refrigerant charge.
 5. Check the condition of filters.
 6. Check the condition of coils.
 7. Check the operation of the drain pan and condensate-drain trap.
 8. Check bearings and other lubricated parts for proper lubrication.
 9. Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.
- B. TAB After Construction: Before performing testing and balancing of renovated existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished in accordance with renovation scope indicated by Contract Documents. Verify the following:
1. New filters are installed.
 2. Coils are clean and fins combed.
 3. Drain pans are clean.
 4. Fans are clean.
 5. Bearings and other parts are properly lubricated.
 6. Deficiencies noted in the preconstruction report are corrected.
- C. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.
1. Compare the indicated airflow of the renovated work to the measured fan airflows, and determine the new fan speed and the face velocity of filters and coils.
 2. Verify that the indicated airflows of the renovated work result in filter and coil face velocities and fan speeds that are within the acceptable limits defined by equipment manufacturer.
 3. If calculations increase or decrease the airflow rates and water flow rates by more than [5] percent, make equipment adjustments to achieve the calculated rates. If increase or decrease is [5] percent or less, equipment adjustments are not required.
 4. Balance each air outlet.

3.29 TOLERANCES

- A. Set HVAC system's airflow rates and water flow rates within the following tolerances:
1. Supply, Return, and Exhaust Fans and Equipment with Fans: **[Plus or minus 5 percent]** [. If design value is less than 100 cfm (4.7 L/s), within 10 cfm (4.7 L/s).
 2. Air Outlets and Inlets: **[Plus or minus 5 percent]**. If design value is less than 100 cfm (4.7 L/s), within 10 cfm (4.7 L/s).
 3. Heating-Water Flow Rate: **[Plus or minus 5 percent]**. If design value is less than 10 gpm (0.63 L/s), within 10 percent.
 4. Chilled-Water Flow Rate: **[Plus or minus 5 percent]**. If design value is less than 10 gpm (0.63 L/s), within 10 percent.
- B. Maintaining pressure relationships as designed shall have priority over the tolerances specified above.

3.30 PROGRESS REPORTING

- A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for system-balancing devices. Recommend changes and additions to system-balancing devices, to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance-measuring and -balancing devices.
- B. Status Reports: Prepare [**weekly**] 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.

3.31 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.
 - 3. Certify validity and accuracy of field data.
- B. Final Report Contents: In addition to certified field-report data, include the following:
 - 1. Pump curves.
 - 2. Fan curves.
 - 3. Manufacturers' test data.
 - 4. Field test reports prepared by system and equipment installers.
 - 5. Other information relative to equipment performance; do not include Shop Drawings and Product Data.
- C. General Report Data: In addition to form titles and entries, include the following data:
 - 1. Title page.
 - 2. Name and address of the TAB specialist.
 - 3. Project name.
 - 4. Project location.
 - 5. Architect's name and address.
 - 6. Engineer's name and address.
 - 7. Contractor's name and address.
 - 8. Report date.
 - 9. Signature of TAB supervisor who certifies the report.
 - 10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.

11. Summary of contents, including the following:
 - a. Indicated versus final performance.
 - b. Notable characteristics of systems.
 - c. Description of system operation sequence if it varies from the Contract Documents.
 12. Nomenclature sheets for each item of equipment.
 13. Data for terminal units, including manufacturer's name, type, size, and fittings.
 14. Notes to explain why certain final data in the body of reports vary from indicated values.
 15. Test conditions for fans 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. Heating coil, dry-bulb conditions.
 - e. Face and bypass damper settings at coils.
 - f. Fan drive settings, including settings and percentage of maximum pitch diameter.
 - g. **[Variable-frequency controller] [Inlet vane]** settings for variable-air-volume systems.
 - h. Settings for pressure controller(s).
 - i. Other system operating conditions that affect performance.
 16. Test conditions for pump performance forms, including the following:
 - a. Variable-frequency controller settings for variable-flow hydronic systems.
 - b. Settings for pressure controller(s).
 - c. 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 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, 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** (mm), and bore.
 - i. Center-to-center dimensions of sheave and amount of adjustments in **inches** (mm).
 - 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 speed.
 - c. Volts, phase, and hertz.
 - d. Full-load amperage and service factor.
 - e. Sheave make, size in **inches** (mm), and bore.
 - f. Center-to-center dimensions of sheave and amount of adjustments in **inches** (mm).
- 3. Test Data (Indicated and Actual Values):
 - a. Total airflow rate in **cfm** (L/s).
 - b. Total system static pressure in **inches wg** (Pa).
 - c. Fan speed.
 - d. Inlet and discharge static pressure in **inches wg** (Pa).
 - e. For each filter bank, filter static-pressure differential in **inches wg** (Pa).
 - f. Preheat-coil static-pressure differential in **inches wg** (Pa).
 - g. Cooling-coil static-pressure differential in **inches wg** (Pa).
 - h. Heating-coil static-pressure differential in **inches wg** (Pa).
 - i. List for each internal component with pressure-drop, static-pressure differential in **inches wg** (Pa).
 - j. Outdoor airflow in **cfm** (L/s).
 - k. Return airflow in **cfm** (L/s).
 - l. Outdoor-air 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** (mm) o.c.
 - f. Make and model number.
 - g. Face area in **sq. ft.** (sq. m).
 - h. Tube size in **NPS** (DN).
 - i. Tube and fin materials.
 - j. Circuiting arrangement.
- 2. Test Data (Indicated and Actual Values):
 - a. Airflow rate in **cfm** (L/s).
 - b. Average face velocity in **fpm** (m/s).
 - c. Air pressure drop in **inches wg** (Pa).
 - d. Outdoor-air, wet- and dry-bulb temperatures in **deg F** (deg C).

- e. Return-air, wet- and dry-bulb temperatures in **deg F (deg C)**.
 - f. Entering-air, wet- and dry-bulb temperatures in **deg F (deg C)**.
 - g. Leaving-air, wet- and dry-bulb temperatures in **deg F (deg C)**.
 - h. Water flow rate in **gpm (L/s)**.
 - i. Water pressure differential in **feet of head or psig (kPa)**.
 - j. Entering-water temperature in **deg F (deg C)**.
 - k. Leaving-water temperature in **deg F (deg C)**.
 - l. Refrigerant expansion valve and refrigerant types.
 - m. Refrigerant suction pressure in **psig (kPa)**.
 - n. Refrigerant suction temperature in **deg F (deg C)**.
- G. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:
- 1. Unit Data:
 - a. System identification.
 - b. Location.
 - c. Make and type.
 - d. Model number and unit size.
 - e. Manufacturer's serial number.
 - f. Fuel type in input data.
 - g. Output capacity in **Btu/h (kW)**.
 - h. Ignition type.
 - i. Burner-control types.
 - j. Motor horsepower and speed.
 - k. Motor volts, phase, and hertz.
 - l. Motor full-load amperage and service factor.
 - m. Sheave make, size in **inches (mm)**, and bore.
 - n. Center-to-center dimensions of sheave and amount of adjustments in **inches (mm)**.
 - 2. Test Data (Indicated and Actual Values):
 - a. Total airflow rate in **cfm (L/s)**.
 - b. Entering-air temperature in **deg F (deg C)**.
 - c. Leaving-air temperature in **deg F (deg C)**.
 - d. Air temperature differential in **deg F (deg C)**.
 - e. Entering-air static pressure in **inches wg (Pa)**.
 - f. Leaving-air static pressure in **inches wg (Pa)**.
 - g. Air static-pressure differential in **inches wg (Pa)**.
 - h. Low-fire fuel input in **Btu/h (kW)**.
 - i. High-fire fuel input in **Btu/h (kW)**.
 - j. Manifold pressure in **psig (kPa)**.
 - k. High-temperature-limit setting in **deg F (deg C)**.
 - l. Operating set point in **Btu/h (kW)**.
 - m. Motor voltage at each connection.
 - n. Motor amperage for each phase.
 - o. Heating value of fuel in **Btu/h (kW)**.

H. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:

1. Unit Data:
 - a. System identification.
 - b. Location.
 - c. Coil identification.
 - d. Capacity in **Btu/h** (**kW**).
 - e. Number of stages.
 - f. Connected volts, phase, and hertz.
 - g. Rated amperage.
 - h. Airflow rate in **cfm** (**L/s**).
 - i. Face area in **sq. ft.** (**sq. m**).
 - j. Minimum face velocity in **fpm** (**m/s**).
2. Test Data (Indicated and Actual Values):
 - a. Heat output in **Btu/h** (**kW**).
 - b. Airflow rate in **cfm** (**L/s**).
 - c. Air velocity in **fpm** (**m/s**).
 - d. Entering-air temperature in **deg F** (**deg C**).
 - e. Leaving-air temperature in **deg F** (**deg C**).
 - f. Voltage at each connection.
 - g. Amperage for each phase.

I. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:
 - a. System identification.
 - b. Location.
 - c. Make and type.
 - d. Model number and size.
 - e. Manufacturer's serial number.
 - f. Arrangement and class.
 - g. Sheave make, size in **inches** (**mm**), and bore.
 - h. Center-to-center dimensions of sheave and amount of adjustments in **inches** (**mm**).
2. Motor Data:
 - a. Motor make, and frame type and size.
 - b. Horsepower and speed.
 - c. Volts, phase, and hertz.
 - d. Full-load amperage and service factor.
 - e. Sheave make, size in **inches** (**mm**), and bore.
 - f. Center-to-center dimensions of sheave and amount of adjustments in **inches** (**mm**).
 - g. Number, make, and size of belts.

3. Test Data (Indicated and Actual Values):

- a. Total airflow rate in **cfm** (L/s).
- b. Total system static pressure in **inches wg** (Pa).
- c. Fan speed.
- d. Discharge static pressure in **inches wg** (Pa).
- e. Suction static pressure in **inches wg** (Pa).

J. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

- a. System fan and air-handling-unit number.
- b. Location and zone.
- c. Traverse air temperature in **deg F** (deg C).
- d. Duct static pressure in **inches wg** (Pa).
- e. Duct size in **inches** (mm).
- f. Duct area in **sq. ft.** (sq. m).
- g. Indicated airflow rate in **cfm** (L/s).
- h. Indicated velocity in **fpm** (m/s).
- i. Actual airflow rate in **cfm** (L/s).
- j. Actual average velocity in **fpm** (m/s).
- k. Barometric pressure in **psig** (Pa).

K. Air-Terminal-Device Reports:

1. Unit Data:

- a. System and air-handling unit identification.
- b. Location and zone.
- c. Apparatus used for test.
- d. Area served.
- e. Make.
- f. Number from system diagram.
- g. Type and model number.
- h. Size.
- i. Effective area in **sq. ft.** (sq. m).

2. Test Data (Indicated and Actual Values):

- a. Airflow rate in **cfm** (L/s).
- b. Air velocity in **fpm** (m/s).
- c. Preliminary airflow rate as needed in **cfm** (L/s).
- d. Preliminary velocity as needed in **fpm** (m/s).
- e. Final airflow rate in **cfm** (L/s).
- f. Final velocity in **fpm** (m/s).
- g. Space temperature in **deg F** (deg C).

- L. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:
1. Unit Data:
 - a. System and air-handling-unit identification.
 - b. Location and zone.
 - c. Room or riser served.
 - d. Coil make and size.
 - e. Flowmeter type.
 2. Test Data (Indicated and Actual Values):
 - a. Airflow rate in **cfm** (L/s).
 - b. Entering-water temperature in **deg F** (deg C).
 - c. Leaving-water temperature in **deg F** (deg C).
 - d. Water pressure drop in **feet of head or psig** (kPa).
 - e. Entering-air temperature in **deg F** (deg C).
 - f. Leaving-air temperature in **deg F** (deg C).
- M. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves, and include the following:
1. Unit Data:
 - a. Unit identification.
 - b. Location.
 - c. Service.
 - d. Make and size.
 - e. Model number and serial number.
 - f. Water flow rate in **gpm** (L/s).
 - g. Water pressure differential in **feet of head or psig** (kPa).
 - h. Required net positive suction head in **feet of head or psig** (kPa).
 - i. Pump speed.
 - j. Impeller diameter in **inches** (mm).
 - k. Motor make and frame size.
 - l. Motor horsepower and rpm.
 - m. Voltage at each connection.
 - n. Amperage for each phase.
 - o. Full-load amperage and service factor.
 - p. Seal type.
 2. Test Data (Indicated and Actual Values):
 - a. Static head in **feet of head or psig** (kPa).
 - b. Pump shutoff pressure in **feet of head or psig** (kPa).
 - c. Actual impeller size in **inches** (mm).
 - d. Full-open flow rate in **gpm** (L/s).
 - e. Full-open pressure in **feet of head or psig** (kPa).
 - f. Final discharge pressure in **feet of head or psig** (kPa).
 - g. Final suction pressure in **feet of head or psig** (kPa).

- h. Final total pressure in **feet of head or psig** (kPa).
- i. Final water flow rate in **gpm** (L/s).
- j. Voltage at each connection.
- k. Amperage for each phase.

N. Instrument Calibration Reports:

1. Report Data:

- a. Instrument type and make.
- b. Serial number.
- c. Application.
- d. Dates of use.
- e. Dates of calibration.

3.32 VERIFICATION OF TAB REPORT

- A. The TAB specialist's test and balance engineer shall conduct the inspection in the presence of **[Architect] [Owner] [Construction Manager] [Commissioning Authority]**.
- B. **[Architect] [Owner] [Construction Manager] [Commissioning Authority]** shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to the lesser of either **[10]** percent of the total measurements recorded or the extent of measurements that can be accomplished in **[a normal 8-hour business day]**.
- C. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
- D. If the number of "FAILED" measurements is greater than **[10]** percent of the total measurements checked during the final inspection, the TAB shall be considered incomplete and shall be rejected.
- E. If recheck measurements find the number of failed measurements noncompliant with requirements indicated, proceed as follows:
 - 1. TAB specialists shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection. All changes shall be tracked to show changes made to previous report.
 - 2. If the second final inspection also fails, Owner may pursue others Contract options to complete TAB work.
- F. Prepare test and inspection reports.

3.33 ADDITIONAL TESTS

- A. Within [90] days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.
- B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 230593

SECTION 230719 - HVAC PIPING INSULATION

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes insulation for HVAC piping systems.
- B. Related Requirements:
 - 1. Section 230713 "Duct Insulation" for duct insulation.
 - 2. Section 230716 "HVAC Equipment Insulation" for equipment insulation.
 - 3. Section 232113.13 "Underground Hydronic Piping" loose-fill pipe insulation in underground piping outside the building.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied, if any).
- B. 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 (300 mm) long by NPS 2 (DN 50).
 - 2. Sheet Form Insulation Materials: 12 inches (300 mm) square.
 - 3. Jacket Materials for Pipe: 12 inches (300 mm) long by NPS 2 (DN 50).
 - 4. Sheet Jacket Materials: 12 inches (300 mm) square.
 - 5. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.3 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer.
- B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.
- C. Field quality-control reports.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or craft training program [, **certified by the Department of Labor, Bureau of Apprenticeship and Training**].
- B. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by Architect. Use materials indicated for the completed Work.
 - 1. Piping Mockups:
 - a. One 10-foot (3-m) section of NPS 2 (DN 50) straight pipe.
 - b. One each of a 90-degree threaded, welded, and flanged elbow.
 - c. One each of a threaded, welded, and flanged tee fitting.
 - d. One NPS 2 (DN 50) or smaller valve and one NPS 2-1/2 (DN 65) or larger valve.
 - e. Four support hangers, including hanger shield and insert.
 - f. One threaded strainer and one flanged strainer with removable portion of insulation.
 - g. One threaded reducer and one welded reducer.
 - h. One pressure temperature tap.
 - i. One mechanical coupling.
 - j. One union.
 - 2. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
 - 3. Notify Architect [**seven**] days in advance of dates and times when mockups will be constructed.
 - 4. Obtain Architect's approval of mockups before starting insulation application.
 - 5. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
 - 6. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
 - 7. Demolish and remove mockups when directed.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation system materials are to be delivered to the Project site in unopened containers. The packaging is to include name of manufacturer, fabricator, type, description, and size [, as well as ASTM standard designation, and maximum use temperature].

1.6 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

1.7 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.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products in accordance with ASTM E84 by a testing agency acceptable to authority having jurisdiction. Factory label insulation, jacket materials, adhesive, mastic, tapes, and cement material containers with appropriate markings of applicable testing agency.
 - 1. **[All Insulation Installed Indoors and Outdoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.]**

2.2 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 are applied.
- B. Products do not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come into contact with stainless steel have a leachable chloride content of less than 50 ppm when tested in accordance with ASTM C871.
- D. Insulation materials for use on austenitic stainless steel are qualified as acceptable in accordance with ASTM C795.

- E. Foam insulation materials do not use CFC or HCFC blowing agents in the manufacturing process.
- F. Flexible Elastomeric: Closed-cell, or expanded-rubber materials; suitable for maximum use temperature between **minus 70 deg F (minus 57 deg C)** and **220 deg F (104 deg C)**. Comply with ASTM C534/C534M, Type I, for tubular materials, Type II for sheet materials.
- G. Glass-Fiber, Preformed Pipe: Glass fibers bonded with a thermosetting resin; suitable for maximum use temperature up to **850 deg F (454 deg C)** in accordance with ASTM C411. Comply with ASTM C547.
 - 1. Preformed Pipe Insulation: Type I, Grade A [**with factory-applied ASJ**].
 - 2. Fabricated shapes in accordance with ASTM C450 and ASTM C585.
 - 3. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
- H. Polyolefin: Polyethylene thermal plastic insulation. Comply with ASTM C1427, Type I, Grade 1, for tubular materials and with Type II, Grade 1, for sheet materials [, **self-seal**].

2.3 ADHESIVES

- A. Materials are 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 and Polyolefin Adhesive: Solvent-based adhesive.
 - 1. Flame-spread index is 25 or less and smoke-developed index is 50 or less as tested in accordance with ASTM E84.
 - 2. Wet Flash Point: Below **0 deg F (minus 18 deg C)**.
 - 3. Service Temperature Range: **40 to 200 deg F (4 to plus 93 deg C)**.
 - 4. Color: [**Black**].
- C. Glass-Fiber and Mineral Wool Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
- D. ASJ Adhesive and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A, for bonding insulation jacket lap seams and joints.

2.4 MASTICS AND COATINGS

- A. Materials are compatible with insulation materials, jackets, and substrates.
- B. Vapor-Retarder Mastic, Water Based: Suitable for indoor use on below-ambient services.
 - 1. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
 - 2. Service Temperature Range: [**Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C)**].
 - 3. Comply with MIL-PRF-19565C, Type II, for permeance requirements [, **with supplier listing on DOD QPD - Qualified Products Database**].
 - 4. Color: [**White**].

- C. Vapor-Retarder Mastic, Solvent Based, Outdoor Use: Suitable for outdoor use on below-ambient services.
 - 1. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
 - 2. Service Temperature Range: **Minus 50 to plus 220 deg F (Minus 46 to plus 104 deg C)**.
 - 3. Color: **[White]**.

2.5 LAGGING ADHESIVES

- A. Adhesives comply with MIL-A-3316C, Class I, Grade A, and are compatible with insulation materials, jackets, and substrates.
 - 1. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.
 - 2. Service Temperature Range: **[0 to plus 180 deg F (Minus 18 to plus 82 deg C)]**.
 - 3. Color: White.

2.6 SEALANTS

- A. Materials are as recommended by the insulation manufacturer and are compatible with insulation materials, jackets, and substrates.
- B. Joint Sealants:
 - 1. Permanently flexible, elastomeric sealant.
 - a. Service Temperature Range: **[Minus 100 to plus 300 deg F (Minus 73 to plus 149 deg C)]**.
 - b. Color: White or gray.
- C. FSK and Metal Jacket Flashing Sealants:
 - 1. Fire- and water-resistant, flexible, elastomeric sealant.
 - 2. Service Temperature Range: **Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C)**.
 - 3. Color: Aluminum.

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. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C1136, Type I.
 - 2. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C1136, Type II.

2.8 FIELD-APPLIED JACKETS

- A. Field-applied jackets comply with ASTM C1136, Type I, unless otherwise indicated.
- B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

C. Metal Jacket:

1. Aluminum Jacket: Comply with **ASTM B209** (**ASTM B209M**), Alloy 3003, 3005, 3105, or 5005, Temper H-14.
 - a. **[Sheet and roll stock ready for shop or field sizing] [Factory cut and rolled to size].**
 - b. Finish and thickness are indicated in field-applied jacket schedules.
 - c. Moisture Barrier for Indoor Applications: **[1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper].**
 - d. Moisture Barrier for Outdoor Applications: **[3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper].**
 - e. Factory-Fabricated Fitting Covers:
 - 1) Same material, finish, and thickness as jacket.
 - 2) Preformed two-piece or gore, 45- and 90-degree, short- and long-radius elbows.
 - 3) Tee covers.
 - 4) Flange and union covers.
 - 5) End caps.
 - 6) Beveled collars.
 - 7) Valve covers.
 - 8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

- D. Underground Direct-Buried Jacket: **125-mil- (3.2-mm-)** thick vapor barrier and waterproofing membrane, consisting of a rubberized bituminous resin reinforced with a woven-glass fiber or polyester scrim and laminated aluminum foil.

2.9 FIELD-APPLIED FABRIC REINFORCING MESH

- A. Woven Glass-Fiber Mesh: Approximately **2 oz./sq. yd. (68 g/sq. m)** with a thread count of **10 strands by 10 strands/sq. in. (4 strands by 4 strands/sq. mm)** for covering pipe and pipe fittings.

2.10 FIELD-APPLIED CLOTHS

- A. Woven Glass-Fiber Cloth: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of **8 oz./sq. yd. (271 g/sq. m)**.

2.11 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C1136.
 1. Width: **[3 inches (75 mm)]**.
 2. Thickness: **[11.5 mils (0.29 mm)]**.
 3. Adhesion: **[90 ounces force/inch (1.0 N/mm)]** in width.
 4. Elongation: **[2]** percent.

5. Tensile Strength: [40 lbf/inch (7.2 N/mm)] in width.
 6. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
- B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C1136.
1. Width: [3 inches (75 mm)].
 2. Thickness: [6.5 mils (0.16 mm)].
 3. Adhesion: [90 ounces force/inch (1.0 N/mm)] in width.
 4. Elongation: [2] percent.
 5. Tensile Strength: [40 lbf/inch (7.2 N/mm)] in width.
 6. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.
- C. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.
1. Width: [2 inches (50 mm)].
 2. Thickness: [3.7 mils (0.093 mm)].
 3. Adhesion: [100 ounces force/inch (1.1 N/mm)] in width.
 4. Elongation: [5] percent.
 5. Tensile Strength: [34 lbf/inch (6.2 N/mm)] in width.

2.12 SECUREMENTS

- A. Bands:
1. Aluminum: ASTM B209 (ASTM B209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch (0.51 mm) thick, [1/2 inch (13 mm)] [3/4 inch (19 mm)] wide with [wing seal] [or] [closed seal].
 2. Springs: Twin spring set constructed of stainless steel, with ends flat and slotted to accept metal bands. Spring size is determined by manufacturer for application.
- B. Staples: Outward-clinching insulation staples, nominal 3/4 inch (19 mm) wide, stainless steel or Monel.
- C. Wire: [0.062-inch (1.6-mm) soft-annealed, stainless steel].

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. Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
- B. Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
 - 1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer **5 mils (0.127 mm)** thick and an epoxy finish **5 mils (0.127 mm)** thick if operating in a temperature range between **140 and 300 deg F (60 and 149 deg C)**. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
 - 2. Carbon Steel: Coat carbon steel operating at a service temperature of between **32 and 300 deg F (0 and 149 deg C)** with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
- C. Coordinate insulation installation with the tradesman installing heat tracing. Comply with requirements for heat tracing that apply to insulation.
- D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping, including fittings, valves, and specialties.
- B. Install insulation materials, forms, vapor barriers or retarders, jackets, and of thicknesses required for each item of pipe system, as specified in insulation system schedules.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, compress, or otherwise damage insulation or jacket.
- D. Install insulation with longitudinal seams at top and bottom (12 o'clock and 6 o'clock positions) of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.
- F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.
- G. Keep insulation materials dry during storage, application, and finishing. Replace insulation materials that get wet during storage or in the installation process before being properly covered and sealed in accordance with the Contract Documents [**, unless otherwise approved by the engineer of record**].
- H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- I. Install insulation with least number of joints practical.

- J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
1. Install insulation continuously through hangers and around anchor attachments.
 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends attached to structure with vapor-barrier mastic.
 3. Install insert materials and insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
 4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- L. Install insulation with factory-applied jackets as follows:
1. Draw jacket tight and smooth, but not to the extent of creating wrinkles or areas of compression in the insulation.
 2. Cover circumferential joints with **3-inch- (75-mm-)** wide strips, of same material as insulation jacket. Secure strips with adhesive and outward-clinching staples along both edges of strip, spaced **4 inches (100 mm)** o.c.
 3. Overlap jacket longitudinal seams at least **1-1/2 inches (38 mm)**. 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 (50 mm)**] [**4 inches (100 mm)**] o.c.
 4. For below-ambient services, apply vapor-barrier mastic over staples.
 5. Cover joints and seams with tape, in accordance with insulation material manufacturer's written instructions, to maintain vapor seal.
 6. 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.
- 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 (100 mm)**] beyond damaged areas. Adhere, staple, and seal patches in similar fashion to butt joints.
- P. For above-ambient services, do not install insulation to the following:
1. Vibration-control devices.
 2. Testing agency labels and stamps.
 3. Nameplates and data plates.

3.4 PENETRATIONS

- A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
1. Seal penetrations with flashing sealant.
 2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 3. Extend jacket of outdoor insulation outside roof flashing at least **2 inches (50 mm)** below top of roof flashing.
 4. Seal jacket to roof flashing with flashing sealant.
- B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.
- C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.
1. Seal penetrations with flashing sealant.
 2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least **2 inches (50 mm)**.
 4. Seal jacket to wall flashing with flashing sealant.
- D. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
- E. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.
1. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping and fire-resistive joint sealers.
- F. Insulation Installation at Floor Penetrations:
1. Pipe: Install insulation continuously through floor penetrations.
 2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.5 GENERAL PIPE INSULATION INSTALLATION

- A. Requirements in this article generally apply to all insulation materials, except where more specific requirements are specified in various pipe insulation material installation articles below.

- B. Insulation Installation on Fittings, Valves, Strainers, Flanges, Mechanical Couplings, and Unions:
1. Install insulation over fittings, valves, strainers, flanges, mechanical couplings, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
 2. Insulate pipe elbows using **[prefabricated fitting insulation]** **[or]** **[mitered or routed fittings]** made from same material and density as that of adjacent pipe insulation. Each piece is 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 **[prefabricated fitting insulation]** **[or]** **[sectional pipe insulation]** of same material and thickness as that used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
 4. Insulate valves using **[prefabricated fitting insulation]** **[or]** **[sectional pipe insulation]** of same material, density, and thickness as that used for adjacent pipe. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
 5. Insulate strainers using **[prefabricated fitting insulation]** **[or]** **[sectional pipe insulation]** of same material, density, and thickness as that used for adjacent pipe. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers, so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.
 6. Insulate flanges, mechanical couplings, and unions using a section of oversized preformed pipe insulation to fit. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Stencil or label the outside insulation jacket of each union with the word "union" matching size and color of pipe labels.
 7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
 8. For services not specified to receive a field-applied jacket, except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing, using PVC tape.
- C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

- D. Install removable insulation covers [**at locations indicated**]. Installation conforms to the following:
1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as that of adjoining pipe insulation.
 2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union at least 2 times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless steel or aluminum bands. Select band material compatible with insulation and jacket.
 3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.
 4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least **2 inches (50 mm)** over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
 5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.6 INSTALLATION OF CALCIUM SILICATE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure single-layer insulation with stainless steel bands at **12-inch (300-mm)** intervals, and tighten bands without deforming insulation materials.
2. Install two-layer insulation with joints tightly butted and staggered at least **3 inches (75 mm)**. Secure inner layer with wire spaced at **12-inch (300-mm)** intervals. Secure outer layer with stainless steel bands at **12-inch (300-mm)** intervals.
3. Apply a skim coat of mineral-fiber, hydraulic-setting cement to insulation surface. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth or tape. Overlap edges at least **1 inch (25 mm)**. Apply finish coat of lagging adhesive over glass cloth or tape. Thin finish coat to achieve smooth, uniform finish.

B. Insulation Installation on Pipe Flanges:

1. Install prefabricated pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as that of pipe insulation. Where voids are difficult to fill with block insulation, fill the voids with a fibrous insulation material suitable for the specific operating temperature.
4. Finish flange insulation same as pipe insulation.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install prefabricated sections of same material as that of straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When prefabricated insulation sections of insulation are not available, install mitered sections of calcium silicate insulation. Secure insulation materials with wire or bands.
3. Finish fittings insulation same as pipe insulation.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install pipe insulation, quads, hex sections, or beveled lag segments, adhered together, of calcium silicate insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
2. Install insulation to flanges as specified for flange insulation application.
3. Finish valve and specialty insulation same as pipe insulation.

3.7 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as that of pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install sections of pipe insulation and miter if required in accordance with manufacturer's written instructions.
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 prefabricated valve covers manufactured of same material as that of pipe insulation when available.
2. When prefabricated 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.

3.8 INSTALLATION OF GLASS-FIBER INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands, and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with jackets on above-ambient surfaces, secure laps with outward-clinched staples at **6 inches (150 mm)** o.c.
4. For insulation with jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install prefabricated 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 glass-fiber or mineral-wool blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least **1 inch (25 mm)**, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install prefabricated sections of same material as that of straight segments of pipe insulation when available.
2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install prefabricated sections of same material as that of straight segments of pipe insulation when available.
2. When prefabricated sections are not available, install fabricated sections of pipe insulation to valve body.
3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
4. Install insulation to flanges as specified for flange insulation application.

3.9 INSTALLATION OF POLYOLEFIN INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Seal split-tube longitudinal seams and end joints with manufacturer's recommended adhesive [, **or via self-seal mechanism**] to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyolefin sheet insulation of same thickness as that of pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of polyolefin pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install cut sections of polyolefin pipe and sheet insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties, and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.10 INSTALLATION OF FIELD-APPLIED JACKETS

A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.

1. Draw jacket smooth and tight to surface with **2-inch (50-mm)** overlap at seams and joints.
2. Embed glass cloth between two **0.062-inch- (1.6-mm-)** thick coats of lagging adhesive.
3. Completely encapsulate insulation with coating, leaving no exposed insulation.

B. Where FSK jackets are indicated, install as follows:

1. Draw jacket material smooth and tight.
2. Install lap or joint strips with same material as jacket.
3. Secure jacket to insulation with manufacturer's recommended adhesive.
4. Install jacket with **1-1/2-inch (38-mm)** laps at longitudinal seams and **3-inch- (75-mm-)** wide joint strips at end joints.
5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

C. Where PVC jackets are indicated and for horizontal applications, install with **1-inch (25-mm)** overlap at longitudinal seams and end joints. Seal with manufacturer's recommended adhesive.

1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.
- D. Where metal jackets are indicated, install with **2-inch (50-mm)** overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless steel bands **12 inches (300 mm)** o.c. and at end joints.

3.11 FINISHES

- A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."
 1. Flat Acrylic Finish: **[Two]** finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
 - a. Finish Coat Material: Interior, flat, latex-emulsion size.
- B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.
- C. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.
- D. Do not field paint aluminum or stainless steel jackets.

3.12 FIELD QUALITY CONTROL

- A. Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform tests and inspections **[with the assistance of a factory-authorized service representative]**.
- D. Tests and Inspections: Inspect pipe, fittings, strainers, and valves, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection is limited to **[three]** 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.
- E. All insulation applications will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports.

3.13 PIPING INSULATION SCHEDULE, GENERAL

- A. Insulation conductivity and thickness per pipe size comply with schedules in this Section or with requirements of authorities having jurisdiction, whichever is more stringent.
- B. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.
- C. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:
 - 1. Underground piping.
 - 2. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

3.14 INDOOR PIPING INSULATION SCHEDULE

- A. Condensate Air Condition drain:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [1/2 inch (15 mm)] thick.
- B. Chilled Water and Cooling Tower Water:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [1/2 inch (15 mm) in conditioned areas and 1 inch (25 mm) in unconditioned areas] thick.
- C. Refrigerant Suction and Hot-Gas Piping:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [1 inch (25 mm)] thick.
- D. Refrigerant Suction and Hot-Gas Flexible Tubing:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [2 inches (50 mm)] thick.
- E. Refrigerant Liquid Piping:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [1 inch (25 mm)] thick.

3.15 OUTDOOR PIPING INSULATION SCHEDULE

- A. Condensate Air Condition drain:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [2 inch (50 mm)] thick.

- B. Chilled Water and Cooling Tower Water:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [2 inches (50 mm)] thick.
- C. Refrigerant Suction and Hot-Gas Piping:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [2 inches (50 mm)] thick.
- D. Refrigerant Suction and Hot-Gas Flexible Tubing:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [2 inches (50 mm)] thick.
- E. Refrigerant Liquid Piping:
 - 1. All Pipe Sizes: Insulation shall be [one of] the following:
 - a. Polyolefin: [2 inches (50 mm)] thick.

3.16 OUTDOOR, UNDERGROUND, PIPING INSULATION SCHEDULE

- A. Insulation for belowground piping is specified in Section 232113.13 "Underground Hydronic Piping".
- B. Chilled Water and Cooling Tower Supply and Return, All Sizes: [2 inches (50 mm)] thick.
- C. Hot-Water Supply and Return, All Sizes: [3 inches (75 mm)] thick.

3.17 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:
 - 1. Aluminum [0.020 inch (0.51 mm)] thick.

3.18 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:
 - 1. Aluminum [0.020 inch (0.51 mm)] thick.

3.19 UNDERGROUND, FIELD-APPLIED INSULATION JACKET

- A. For underground direct-buried piping applications, install underground direct-buried jacket over insulation material.

END OF SECTION 230719

SECTION 230800 - 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.

1.2 SUMMARY

- A. Section includes Cx process requirements for the following HVAC systems, assemblies, and equipment:
 - 1. Energy supply systems.
 - 2. Heat generation systems.
 - 3. Cooling generation systems.
 - 4. Central-station air-handling systems.
 - 5. Air, and hydronic distribution systems.
 - 6. HVAC controls.
 - 7. TAB verification.
- B. Related Requirements:
 - 1. Section 019113 "General Commissioning Requirements" for general Cx process requirements and CxA responsibilities.
 - 2. For construction checklists, comply with requirements in various Division 23 Sections specifying HVAC systems, system components, equipment, and products.

1.3 DEFINITIONS

- A. BAS: Building automation system.
- B. Cx: Commissioning, as defined in Section 019113 "General Commissioning Requirements."
- C. CxA: Commissioning Authority, as defined in Section 019113 "General Commissioning Requirements."
- D. "Systems," "Assemblies," "Subsystems," "Equipment," and "Components": Where these terms are used together or separately, they mean "as-built" systems, assemblies, subsystems, equipment, and components.
- E. TAB: Testing, adjusting, and balancing.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For **[BAS]** **[and]** **[HVAC]** testing technician.
- B. Construction Checklists:
 - 1. Draft Cx plan, including draft construction checklists to be prepared by CxA under Section 019113 "General Commissioning Requirements." Div. 23 Subcontractor is to review Construction Checklist in accordance with requirements in Section 019113 "General Commissioning Requirements" and ASHRAE 202 and to resolve any issues with the CxA.
- C. Test Equipment and Instruments: For all test equipment and instruments to be used in conducting Cx tests by Div. 23 Subcontractor, provide the following:
 - 1. Equipment/instrument identification number.
 - 2. Planned Cx application or use.
 - 3. Manufacturer, make, model, and serial number.
 - 4. Calibration history, including certificates from agencies that calibrate the equipment and instrumentation.
 - 5. Equipment manufacturers' proprietary instrumentation and tools. For each instrument or tool, identify the following:
 - a. Instrument or tool identification number.
 - b. Equipment schedule designation of equipment for which the instrument or tool is required.
 - c. Manufacturer, make, model, and serial number.
 - d. Calibration history, including certificates from agencies that calibrate the instrument or tool, where appropriate.

1.5 QUALITY ASSURANCE

- A. BAS Testing Technician Qualifications: Technicians performing BAS Construction Checklist verification tests, Construction Checklist verification test demonstrations, Cx tests, and Cx test demonstrations are to have the following minimum qualifications:
 - 1. Journey level or equivalent skill level with knowledge of BAS, HVAC, electrical concepts, and building operations.
 - 2. Minimum **[five years']** experience installing, servicing, and operating systems manufactured by approved manufacturer.
 - 3. International Society of Automation (ISA)-Certified Control Systems Technician (CCST) Level I.

- B. HVAC Testing Technician Qualifications: Technicians to perform HVAC Construction Checklist verification tests, Construction Checklist verification test demonstrations, Cx tests, and Cx test demonstrations shall have the following minimum qualifications:
1. Journey level or equivalent skill level; vocational school four-year-program graduate or an Associate's 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 systems, electrical concepts, building operations, and application and use of tools and instrumentation to measure performance of HVAC equipment, assemblies, and systems.
 2. Minimum **[five years']** experience that is to include installing, servicing, and operating systems manufactured by approved manufacturer.
- C. Testing Equipment and Instrumentation Quality and Calibration:
1. Capable of testing and measuring performance within the specified acceptance criteria.
 2. Be calibrated at manufacturer's recommended intervals with current calibration tags permanently affixed to the instrument being used.
 3. Be maintained in good repair and operating condition throughout duration of use on Project.
 4. 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 Cx 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, shall comply with the following:
 - a. Be calibrated by manufacturer with current calibration tags permanently affixed.
 - b. Include a separate list of proprietary test instrumentation and tools in operation and maintenance manuals.
 2. HVAC proprietary test instrumentation and tools become property of Owner at the time of Substantial Completion.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 Cx PROCESS:

- A. Perform Cx process in accordance with Section 019113 "General Commissioning Requirements" for **[BAS]** **[and]** **[HVAC]** and in accordance with the following:
1. **[Cx standards acceptable to the authority having jurisdiction].**

3.2 CONSTRUCTION CHECKLISTS

- A. Preliminary detailed construction checklists are to be prepared under Section 019113 "General Commissioning Requirements" for each **[BAS] [and] [HVAC]** system, assembly, subsystem, equipment, and component required to be commissioned, as detailed in **[Cx standards acceptable to the authority having jurisdiction and] ASHRAE 202**. Contractor performs the following:
1. Review **[BAS] [and] [HVAC]** preliminary construction checklists and provide written comments on checklist items where appropriate.
 2. Return preliminary Construction Checklist with review comments within **[10] <Insert number>** days of receipt.
 3. When review comments have been resolved, the CxA will provide final construction checklists marked "Approved for Use, (date)."
 4. Use only construction checklists marked "Approved for Use, (date)" When performing tests. Mark construction checklists in the appropriate place as indicated Project events are completed, and provide pertinent details and other information.
- B. Prepare preliminary detailed construction checklists for each **[BAS] [and] [HVAC]** system, assembly, subsystem, equipment, and component required to be commissioned, as detailed in **[Cx standards acceptable to the authority having jurisdiction and ASHRAE 202]**.
1. Submit preliminary construction checklists to CxA and Designer for review.
 2. When review comments have been resolved, the CxA will provide final construction checklists marked "Approved for Use, (date)."
 3. Use only construction checklists, marked "Approved for Use, (date)" when performing tests. Mark construction checklists in the appropriate place, as indicated Project events are completed and provide pertinent details and other information.
- C. Additional systems required to be commissioned:
1. Energy supply systems, including the following:
 - a. Fuel-oil supply.
 - b. Fuel gas supply.
 - c. Central-plant hot-water supply.
 - d. Solar-energy supply.
 - e. Renewable energy systems.
 - f. Energy storage systems.
 - g. Demand-control systems.
 2. Heat generation systems, including the following:
 - a. Boilers.
 - b. Fuel-fired unit heaters.
 - c. Auxiliary equipment.
 3. Cooling generation systems, including the following:
 - a. Water chillers.
 - b. Direct-expansion refrigeration systems.

4. Air-handling systems, including the following:
 - a. Supply, return, and exhaust air fans, motors, and drives.
 - b. Automatic and gravity dampers.
 - c. Heating and cooling devices.
 - d. Humidification and dehumidification devices.
 - e. Air filters.
 - f. Hangers and supports.
 - g. Interlock between air-handling system and fire/smoke alarm system.
5. Air duct systems, including the following:
 - a. Duct systems.
 - b. Air-duct accessories, including volume dampers, fire and smoke dampers, turning vanes, sound attenuators, and flexible connectors.
 - c. Duct-mounted access doors and panels.
 - d. Hangers and supports.
6. Air curtain systems.
 - a. Supply air fans and motors.
 - b. Heating and cooling devices.
7. Steam and hydronic distribution systems, including the following:
 - a. Steam distribution piping systems.
 - b. Condensate piping systems, including condensate pumps and all accessories.
 - c. Hydronic piping systems and all accessories.
 - d. Pumps and all accessories.
 - e. Sleeves and sleeve seals.
 - f. Meters and gauges.
 - g. General-duty and specialty valves.
 - h. Hangers and supports
8. Refrigerant piping, including the following:
 - a. Refrigerant piping, fittings, and specialties.
 - b. Refrigerant charge.
 - c. Sleeves and sleeve seals.
 - d. Meters and gauges.
 - e. General-duty and specialty valves.
 - f. Hangers and supports.
9. Smoke-control systems, including the following:
 - a. Exhaust and makeup fans, motors, and drives.
 - b. Exhaust and makeup air distribution systems.
 - c. Smoke dampers.
 - d. Smoke detectors.
 - e. Fire and smoke alarm system interface.

10. Heating and cooling terminal and unitary equipment, including the following:
 - a. Unit ventilators.
 - b. Fan-coil units.
 - c. Finned-tube radiation.
 - d. Electric heating.
 - e. Unitary heating and cooling equipment.
11. Vibration isolation systems.
12. Controls and instrumentation, including the following:
 - a. Energy monitoring and recording system.
 - b. Controllers and sensors.
 - c. Automatic control valves, dampers, and actuators.
 - d. Control interface with fans, pumps, dampers, and other equipment and systems.
 - e. Demand-control systems.
13. TAB Verification:
 - a. Airflow.
 - b. Water flow.
 - c. Space pressurization.
14. Documentation:
 - a. Mechanical systems manuals.
 - b. Documentation of required commissioning.
15. Mechanical insulation, including the following:
 - a. Duct and plenum insulation.
 - b. HVAC piping insulation.

3.3 Cx TESTING PREPARATION

- A. Certify that HVAC systems, subsystems, and equipment have been installed, calibrated, and started and that they are operating in accordance with the Contract Documents and approved submittals.
- B. Certify that HVAC instrumentation and control systems have been completed and calibrated, point-to-point checkout has been successfully completed, and systems are operating in accordance with their design sequence of operation, Contract Documents, and approved submittals. Certify that all sensors are operating within specified accuracy and all systems are set to and maintaining set points as required by the design documents.
- 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 in accordance with approved test procedures (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

3.4 Cx TEST CONDITIONS

- A. 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 CxA, and document simulated conditions and methods of simulation. After tests, return configurations and settings to normal operating conditions.
 - 2. Cx test procedures may direct that set points be altered when simulating conditions is impractical.
 - 3. Cx test procedures may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are impractical.
- B. If tests cannot be completed because of a deficiency outside the scope of the HVAC system, document the deficiency and report it to Architect. After deficiencies are resolved, reschedule tests.
- C. If seasonal testing is specified, complete appropriate initial performance tests and documentation, and schedule seasonal tests.

3.5 Cx TESTS COMMON TO HVAC SYSTEMS

- A. Measure capacities and effectiveness of systems, assemblies, subsystems, equipment, and components, including operational and control functions, to verify compliance with acceptance criteria.
- B. Test systems, assemblies, subsystems, equipment, and components for operating modes, interlocks, control responses, responses to abnormal or emergency conditions, and response in accordance with acceptance criteria.
- C. Coordinate schedule with, and perform Cx activities at the direction of, CxA.
- D. Comply with Construction Checklist requirements, including material verification, installation checks, startup, and performance test requirements specified in Division 23 Sections specifying HVAC systems and equipment.
- E. Provide technicians, instrumentation, tools, and equipment to perform and document the following:
 - 1. Cx Construction Checklist verification tests.
 - 2. Cx Construction Checklist verification test demonstrations.

3.6 CONSTRUCTION CHECKLIST EXAMPLES

A. Vibration Isolation in HVAC Systems:

1. Prerequisites: Acceptance of results of construction checklists for vibration [**and seismic**] control devices specified in [Section 230548 "Vibration and Seismic Controls for HVAC Piping and Equipment"] [Section 230548.13 "Vibration Controls for HVAC Piping and Equipment"].
2. Components to Be Tested:
 - a. Vibration isolation control devices in HVAC systems.
 - b. Support systems.
3. Test Purpose: Evaluate effectiveness of vibration isolation control devices.
4. Test Conditions, Variable Speed Equipment: Measure vibration of the facility structure at [three] locations designated by Owner's witness at the following operating conditions:
 - a. Maximum speed.
 - b. Minimum speed.
 - c. Critical speed.
5. Acceptance Criteria: Structure-borne vibration not to exceed specified performance.

3.7 TAB VERIFICATION

- A. Prerequisites: Completion of "Examination" Article requirements and correction of deficiencies, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
- B. 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."
- C. Scope: HVAC air systems and hydronic piping systems.
- D. Purpose: Differential flow relationships intended to maintain air and water pressurization differentials between the various areas of Project.
- E. Conditions of the Test:
 1. Cx Test Demonstration Sampling Rate: As specified in "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
 2. Systems operating in full heating mode [**with minimum outside-air volume**].
 3. Systems operating in full cooling mode [**with minimum outside-air volume**].
 4. For measurements at air-handling units with economizer controls; systems operating in economizer mode with 100 percent outside air.
- F. Acceptance Criteria:
 1. Under all conditions, rechecked measurements comply with "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

2. Additionally, no rechecked measurement shall differ from measurements documented in the final report by more than the tolerances allowed.
3. 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.

3.8 HEATING CONTROL SYSTEM Cx TESTS

A. Heating-Water Supply Temperature Control:

1. Prerequisites: Installation verification of the following:
 - a. Startup of **[boiler]**.
 - b. Startup of heating-water pump(s)
 - c. TAB of heating-water flow and pressure.
 - d. Input Device: Heating-water supply temperature; **[thermostat] [resistance temperature sensor]**.
 - e. Output Device: Control valve.
 - f. Display the following at the operator's workstation:
 - 1) Heating-water supply temperature.
 - 2) Heating-water supply temperature set point.
 - 3) Control-valve position.
2. Scope: Heating-water system.
3. Purpose: Control of heating-water supply temperature at input device.
4. Conditions of the Test:
 - a. Minimum heating-water flow.
 - b. Midrange Heating-Water Flow: **[50 to 60]** percent of maximum.
 - c. Maximum heating-water flow.
5. Acceptance Criteria: Under all conditions, heating-water supply temperature is within plus or minus **[2.0 deg F (1.1 deg C)]** of set point.

B. Heating-Water Supply Temperature Reset:

1. Prerequisites: Installation verification of the following:
 - a. Startup of **[boiler]**.
 - b. Startup of heating-water pump(s).
 - c. TAB of heating-water flow and pressure.
 - d. Input Device: Heating-water supply temperature; **[thermostat] [resistance temperature sensor]**.
 - e. Input Device: Outdoor-air temperature; **[outdoor-air sensor]**.
 - f. Output Device: Control valve.
 - g. Display the following at the operator's workstation:
 - 1) Outdoor-air temperature.
 - 2) Heating-water supply temperature.

- 3) Heating-water supply temperature set point.
 - 4) Control-valve position.
2. Scope: Heating-water system.
 3. Purpose: Control of heating-water supply temperature at heating-water supply temperature input device in response to variable outdoor-air temperature input; [**outdoor-air sensor**].
 4. Conditions of the Test: Outdoor-air temperature input value may be overridden for this test.
 - a. Low Temperature: Outdoor-air temperature between [**minus 30 and 0 deg F (minus 34 and minus 18 deg C)**].
 - b. Midrange Temperature: Outdoor-air temperature between [**30 and 45 deg F (minus 1 and plus 7 deg C)**].
 - c. High Temperature: Outdoor-air temperature above [**65 deg F (18 deg C)**].
 5. Acceptance Criteria: Heating-water supply temperature resets in straight-line relationship with outdoor-air temperature for the following reset schedule. Under all conditions, heating-water supply temperature is within [**2.0 deg F (1.1 deg C)**] of set point.
 - a. [**195 deg F (90 deg C)**] heating water when outdoor-air temperature is [**minus 30 deg F (minus 34 deg C)**].
 - b. [**130 deg F (54 deg C)**] heating water when outdoor-air temperature is [**65 deg F (18 deg C)**].
 - c. Under all conditions, heating-water supply temperature is within plus or minus [**2.0 deg F (1.1 deg C)**] of set point.

C. Control Primary Circulating Pump(s):

1. Prerequisites: Installation verification of the following:
 - a. Startup of heating-water pump(s).
 - b. Input Device: Outdoor-air temperature; [**outdoor-air sensor**].
 - c. Output Device: Heating-water pump; [**starter**] [**DDC system command to starter**] relay.
 - d. Display the following at the operator's workstation:
 - 1) Outdoor-air temperature.
 - 2) Operating status of primary circulating pump(s).
2. Scope: Heating-water pump(s) and associated controls.
3. Purpose: On-off control of heating-water pump(s) in response to variable outdoor-air temperature input; [**outdoor-air sensor**].
4. Conditions of the Test:
 - a. High Temperature: Outdoor-air temperature above [**65 deg F (18 deg C)**].
 - b. Low Temperature: Outdoor-air temperature below [**65 deg F (18 deg C)**].

5. Acceptance Criteria:

- a. High Temperature: Pump(s) are off when outside-air temperature is above [**65 deg F (18 deg C)**].
- b. Low Temperature: Pump(s) are on when outside-air temperature is below [**65 deg F (18 deg C)**].

3.9 CHILLER SYSTEM Cx TESTS

A. Start-and-Stop Chilled-Water Pump(s):

1. Prerequisites: Installation verification of the following:

- a. Startup of chilled-water pump(s).
- b. Output Device: [**Starter**] [**DDC system command to starter**] relay.
- c. Display one of the following at the operator's workstation:
 - 1) Chilled-water flow indication.
 - 2) Chilled-water pump(s) on-off status.
 - 3) Chilled-water pump(s) on-off indication.

2. Scope: Chilled-water system, including chilled-water pump(s), associated controls, and condenser-water system controls.

3. Purpose:

- a. Chilled-water pump(s) start.
- b. Chilled-water pump(s) shutdown.

4. Conditions of the Test:

- a. Verify Start: Start with chilled-water pump enable-input device in the "disable" state to prevent pump start. Place the enable-input device in the "enable" state.
- b. Verify Shutdown: Start with the enable-input device in the "enable" state to allow the pump(s) to run. Then place the enable-input device in the "disable" state.

5. Acceptance Criteria:

- a. Start: Chilled-water pump(s) start when, and only when, the enable-input device is in the "enable" state.
- b. Shutdown: The enable-input device stops the chilled-water pump(s) when placed in the "disable" state.

B. Alternative Chiller(s):

1. Prerequisites: Installation verification of the following:

- a. Input Device: [**Electric alternator**] [**DDC system software**].
- b. Output Device: [**Chiller**] [**DDC system command to chiller**] terminal strip.

- c. Display:
 - 1) Chiller(s) on-off indication.
 - 2) Chiller failure alarm.
- 2. Scope:
 - a. Chilled-water system and associated controls.
- 3. Purpose:
 - a. Adding and dropping chillers as follows.
 - b. Replacement of failed chiller in add/drop sequence.
 - c. Chiller failure alarm initiation.
- 4. Conditions of the Test:
 - a. Lead-Lag Rotation - Chiller Start: Create a number of chilled-water system start-stop cycles equal to the number of chillers plus one.
 - b. Lead-Lag Rotation - Lead Chiller Fail: Disable the lead chiller while it is running.
 - c. Lead-Lag Rotation - Lag Chiller Fail: Disable a lag chiller while it is running.
 - d. Lead-Lag Rotation - Chiller Start Fail: Disable a chiller while it is in standby mode. Initiate a lead-lag rotation call for the disabled chiller to start.
- 5. Acceptance Criteria:
 - a. Lead-Lag Rotation - Chiller Start: On each chilled-water system start event, the **[other]** chiller in rotation starts as the lead chiller, and the previous lead chiller, is designated as the **[last-]** lag chiller.
 - b. Lead-Lag Rotation - Lead Chiller Fail: When the lead chiller fails, the **[other]** chiller in rotation starts as the lead chiller, and a chiller failure alarm, is initiated for the failed chiller.
 - c. Lead-Lag Rotation - Lag Chiller Fail: When the lag chiller fails, **[the next chiller in rotation starts as the lead chiller, and]** a chiller failure alarm is initiated for the failed chiller.
 - d. Lead-Lag Rotation - Chiller Start Fail: When a chiller fails to start, **[the next chiller in rotation starts in its place, and]** a chiller failure alarm is initiated for the failed chiller.

3.10 AIR-HANDLING SYSTEM Cx TESTS

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

- 1. Prerequisites: Installation verification of the following:
 - a. Volume-Control Input Device: **[Differential-pressure switch]** sensing supply-duct static pressure referenced to conditioned-space static pressure.
 - b. Volume-Control Output Device: **[DDC system analog output]** to modulating damper actuator. Set inlet guide vanes to **[closed]** position when fan is stopped.
 - c. Volume-Control Input Device: **[Differential-pressure switch]** sensing supply-duct static pressure referenced to conditioned-space static pressure.

- d. Volume-Control Output Device: [**DDC system analog output**] to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
 - e. High-Pressure Input Device: Static-pressure transmitter sensing supply-duct static pressure referenced to static pressure outside the duct.
2. Scope: VAV 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 [**2**] 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 [**2**] percent.

B. Air-Handler Mixed-Air Control:

1. Prerequisites: Installation verification of the following:
 - a. Minimum Position Input Device: [**DDC system time schedule**].
 - b. Output Device: [**DDC system analog output**] to modulating damper actuator(s).
 - c. Heating Reset Input Device: [**Room thermostat**].
 - d. [**Supply**] [**Mixed**]-Air Temperature Input Device: [**Electronic temperature sensor**].
 - e. Cooling Reset Input Device: Outdoor- and return-air, duct-mounted [**thermostats**].
 - f. Display the following at the operator's workstation:
 - 1) Mixed-air-temperature indication.
 - 2) Mixed-air-temperature set point.
 - 3) Mixed-air damper position.
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**] [**Mixed**]-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] [Mixed]-Air Temperature Control: Override [supply] [mixed]-air temperature set point to a value [2.0 deg F (1.1 deg C)] above current [supply] [mixed]-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] intervals. Submit trend data for [24-hour] periods in which natural conditions require heating reset control, [supply] [mixed]-air temperature control, and cooling reset control.
 - 1) Minimum position input device.
 - 2) Heating reset input device.
 - 3) [Supply] [Mixed]-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 [opens minimum outdoor-air dampers].
 - c. Heating Reset Control: Controller [closes minimum outdoor-air dampers].
 - d. [Supply] [Mixed]-Air Temperature Control: Controller modulates outdoor-, return-, and relief-air dampers to maintain temporary [supply] [mixed]-air temperature set point, plus or minus [1.0 deg F (0.6 deg C)].
 - 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 verify control in accordance with sequence of control.

END OF SECTION 230800

SECTION 230923 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Direct digital control (DDC) system equipment and components for monitoring and controlling of HVAC, exclusive of instrumentation and control devices.

B. Related Requirements:

1. Section 230923.13 "Energy Meters" for thermal and electric power energy meters that connect to DDC systems.
2. Section 230923.17 "Level Instruments" for liquid-level switches, sensors, and transmitters that connect to DDC systems.
3. Section 230923.22 "Position Instruments" for limit switches that connect to DDC systems.
4. Section 230923.33 "Vibration Instruments" for vibration instruments that connect to DDC systems.
5. Section 230923.43 "Weather Stations" for weather stations that connect to DDC systems.
6. Section 230993.11 "Sequence of Operations for HVAC DDC" for control sequences in DDC systems.
7. Section 270553 "Identification for Communications Systems" for identification requirements for communications components.

1.2 DEFINITIONS

- A. Algorithm: A logical procedure for solving a recurrent mathematical problem. A prescribed set of well-defined rules or processes for solving a problem in a finite number of steps.

- B. Analog: A continuously varying signal value, such as current, flow, pressure, or temperature.

C. BACnet Specific Definitions:

1. BACnet: Building Automation Control Network Protocol, ASHRAE 135. A communications protocol allowing devices to communicate data and services over a network.
2. BACnet Interoperability Building Blocks (BIBBs): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.
3. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.
4. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE 135, operated under direction of BACnet International.

- D. Binary: Two-state signal where a high signal level represents "ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Digital" is sometimes used interchangeably with "Binary" to indicate a two-state signal.
- E. Controller: Generic term for any standalone, microprocessor-based, digital controller residing on a network, used for local or global control. Three types of controllers are indicated: network controllers, programmable application controllers, and application-specific controllers.
- F. Control System Integrator: An entity that assists in expansion of existing enterprise system and support of additional operator interfaces to I/O being added to existing enterprise system.
- G. COV: Changes of value.
- H. DDC System Provider: Authorized representative of, and trained by, DDC system manufacturer and responsible for execution of DDC system Work indicated.
- I. Distributed Control: Processing of system data is decentralized and control decisions are made at subsystem level. System operational programs and information are provided to remote subsystems and status is reported back. On loss of communication, subsystems to be capable of operating in a standalone mode using the last best available data.
- J. E/P: Voltage to pneumatic.
- K. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.
- L. HLC: Heavy load conditions.
- M. I/O: System through which information is received and transmitted. I/O refers to analog input (AI), binary input (BI), analog output (AO) and binary output (BO). Analog signals are continuous and represent control influences such as flow, level, moisture, pressure, and temperature. Binary signals convert electronic signals to digital pulses (values) and generally represent two-position operating and alarm status. "Digital," (DI) and (DO), is sometimes used interchangeably with "Binary," (BI) and (BO), respectively.
- N. I/P: Current to pneumatic.
- O. LAN: Local area network.
- P. LNS: LonWorks Network Services.
- Q. LON Specific Definitions:
 - 1. FTT-10: Echelon Transmitter-Free Topology Transceiver.
 - 2. LonMark International: Association comprising suppliers and installers of LonTalk products. Association provides guidelines for implementing LonTalk protocol to ensure interoperability through a standard or consistent implementation.
 - 3. LonTalk: An open standard protocol developed by Echelon Corporation that uses a "Neuron Chip" for communication. LonTalk is a register trademark of Echelon.
 - 4. LonWorks: Network technology developed by Echelon.

5. Node: Device that communicates using CTA-709.1-D protocol and that is connected to a CTA-709.1-D network.
 6. Node Address: The logical address of a node on the network, consisting of a Domain number, Subnet number, and Node number. "Node number" portion of an address is a number assigned to device during installation, is unique within a subnet, and is not a factory-set unique Node ID.
 7. Node ID: A unique 48-bit identifier assigned at factory to each CTA-709.1-D device. Sometimes called a "Neuron ID."
 8. Program ID: An identifier (number) stored in a device (usually, EEPROM) that identifies node manufacturer, functionality of device (application and sequence), transceiver used, and intended device usage.
 9. Standard Configuration Property Type (SCPT): Pronounced "skip-it." A standard format type maintained by LonMark for configuration properties.
 10. Standard Network Variable Type (SNVT): Pronounced "snivet." A standard format type maintained by LonMark used to define data information transmitted and received by individual nodes. "SNVT" is used in two ways. It is an acronym for "Standard Network Variable Type" and is often used to indicate a network variable itself (i.e., it can mean "a network variable of a standard network variable type").
 11. Subnet: Consists of a logical grouping of up to 127 nodes, where logical grouping is defined by node addressing. Each subnet is assigned a number, which is unique within a Domain. See "Node Address."
 12. TP/FT-10: Free Topology Twisted Pair network defined by CTA-709.3 and is most common media type for a CTA-709.1-D control network.
 13. TP/XF-1250: High-speed, 1.25 Mbps, twisted-pair, doubly terminated bus network defined by "LonMark Interoperability Guidelines" and typically used only to connect multiple TP/FT-10 networks.
 14. User-Defined Configuration Property Type (UCPT): Pronounced "u-keep-it." A Configuration Property format type that is defined by device manufacturer.
 15. User-Defined Network Variable Type (UNVT): Network variable format defined by device manufacturer. UNVTs create non-standard communications that other vendors' devices may not correctly interpret and may negatively impact system operation. UNVTs are not allowed.
- R. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- S. Mobile Device: A data-enabled phone or tablet computer capable of connecting to a cellular data network and running a native control application or accessing a web interface.
- T. Modbus TCP/IP: An open protocol for exchange of process data.
- U. MS/TP: Master-slave/token-passing, ISO/IEC/IEEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.
- V. MTBF: Mean time between failures.
- W. Network Controller: Digital controller, which supports a family of programmable application controllers and application-specific controllers, that communicates on peer-to-peer network for transmission of global data.

- X. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.
- Y. Peer to Peer: Networking architecture that treats all network stations as equal partners.
- Z. POT: Portable operator's terminal.
- AA. RAM: Random access memory.
- BB. RF: Radio frequency.
- CC. Router: Device connecting two or more networks at network layer.
- DD. Server: Computer used to maintain system configuration, historical and programming database.
- EE. TCP/IP: Transport control protocol/Internet protocol.
- FF. UPS: Uninterruptible power supply.
- GG. USB: Universal Serial Bus.
- HH. User Datagram Protocol (UDP): This protocol assumes that the IP is used as the underlying protocol.
- II. VAV: Variable air volume.
- JJ. WLED: White light emitting diode.

1.3 PREINSTALLATION MEETINGS

- A. Preinstallation Conference: Conduct conference at **[Project site]** .

1.4 ACTION SUBMITTALS

- A. Multiple Submissions:

1. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.
2. Clearly identify each submittal requirement indicated and in which submission the information will be provided.
3. Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

- B. Product Data:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.

2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation, operation, and maintenance instructions including factors effecting performance.
5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.
 - a. Workstations.
 - b. Printers.
 - c. Servers.
 - d. Gateways.
 - e. Routers.
 - f. Protocol analyzers.
 - g. DDC controllers.
 - h. Enclosures.
 - i. Electrical power devices.
 - j. UPS units.
 - k. Accessories.
 - l. Instruments.
 - m. Control dampers and actuators.
 - n. Control valves and actuators.
6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
7. Each submitted piece of product literature to clearly cross reference specification and drawings that submittal is to cover.

C. Software Submittal:

1. Cross-referenced listing of software to be loaded on each operator workstation, server, gateway, and DDC controller.
2. Description and technical data of all software provided and cross-referenced to products in which software will be installed.
3. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
4. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
5. Listing and description of each engineering equation used with reference source.
6. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
7. Description of operator interface to alphanumeric and graphic programming.
8. Description of each network communication protocol.
9. Description of system database, including all data included in database, database capacity, and limitations to expand database.

10. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden, and system throughout.
11. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

D. Shop Drawings:

1. General Requirements:
 - a. Include cover drawing with Project name, location, Owner, Architect, Contractor, and issue date with each Shop Drawings submission.
 - b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
2. Include plans, elevations, sections, and mounting details where applicable.
3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail means of vibration isolation and show attachments to rotating equipment.
5. Plan Drawings indicating the following:
 - a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork, and piping.
 - b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
 - c. Each desktop workstation network port, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
 - d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
 - e. Network communication cable and raceway routing.
 - f. Proposed routing of wiring, cabling, conduit, and tubing; coordinated with building services for review before installation.
6. Schematic drawings for each controlled HVAC system indicating the following:
 - a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
 - b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
 - c. A graphic showing location of control I/O in proper relationship to HVAC system.
 - d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
 - e. Unique identification of each I/O that to be consistently used between different drawings showing same point.
 - f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays, and interface to DDC controllers.
 - g. Narrative sequence of operation.

- h. Graphic sequence of operation, showing all inputs and output logical blocks.
- 7. Control panel drawings indicating the following:
 - a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
 - b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates, and allocated spare space.
 - c. Front, rear, and side elevations and nameplate legend.
 - d. Unique drawing for each panel.
- 8. DDC system network riser diagram indicating the following:
 - a. Each device connected to network with unique identification for each.
 - b. Interconnection of each different network in DDC system.
 - c. For each network, indicate communication protocol, speed and physical means of interconnecting network devices, such as copper cable type, or optical fiber cable type. Indicate raceway type and size for each.
 - d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.
- 9. DDC system electrical power riser diagram indicating the following:
 - a. Each point of connection to field power with requirements (volts/phase/hertz/amperes/connection type) listed for each.
 - b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.
 - c. Each product requiring power with requirements (volts/phase/hertz/amperes/connection type) listed for each.
 - d. Power wiring type and size, race type, and size for each.
- 10. Monitoring and control signal diagrams indicating the following:
 - a. Control signal cable and wiring between controllers and I/O.
 - b. Point-to-point schematic wiring diagrams for each product.
 - c. Control signal tubing to sensors, switches, and transmitters.
 - d. Process signal tubing to sensors, switches, and transmitters.
 - e. actuators, pilot-positioners if applicable, and associated transducers.
- 11. Color graphics indicating the following:
 - a. Itemized list of color graphic displays to be provided.
 - b. For each display screen to be provided, a true color copy showing layout of pictures, graphics, and data displayed.
 - c. Intended operator access between related hierarchical display screens.

E. System Description:

1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.
2. Complete listing and description of each report, log and trend for format and timing, and events that initiate generation.
3. System and product operation under each potential failure condition including, but not limited to, the following:
 - a. Loss of power.
 - b. Loss of network communication signal.
 - c. Loss of controller signals to inputs and outputs.
 - d. Operator workstation failure.
 - e. Server failure.
 - f. Gateway failure.
 - g. Network failure.
 - h. Controller failure.
 - i. Instrument failure.
 - j. Control damper and valve actuator failure.
4. Complete bibliography of documentation and media to be delivered to Owner.
5. Description of testing plans and procedures.
6. Description of Owner training.

F. Samples:

1. For each of the following exposed product(s), installed in finished space for approval of selection of aesthetic characteristics:
 - a. Gas instruments specified in Section 230923.16 "Gas Instruments."
 - b. Moisture instruments specified in Section 230923.19 "Moisture Instruments."
 - c. Motion instruments specified in Section 230923.21 "Motion Instruments."
 - d. Pressure instruments specified in Section 230923.23 "Pressure Instruments."
 - e. Temperature instruments specified in Section 230923.27 "Temperature Instruments."

G. Delegated Design Submittals: For DDC system products and installation indicated as being delegated.

1. Supporting documentation showing DDC system design complies with performance requirements indicated, including calculations and other documentation necessary to prove compliance.
2. Schedule and design calculations for control dampers and actuators.
 - a. Flow at Project design and minimum flow conditions.
 - b. Face velocity at Project design and minimum airflow conditions.
 - c. Pressure drop across damper at Project design and minimum airflow conditions.
 - d. AMCA 500-D damper installation arrangement used to calculate and schedule pressure drop, as applicable to installation.
 - e. Maximum close-off pressure.

- f. Leakage airflow at maximum system pressure differential (fan close-off pressure).
 - g. Torque required at worst case condition for sizing actuator.
 - h. Actuator selection indicating torque provided.
 - i. Actuator signal to control damper (on, close, or modulate).
 - j. Actuator position on loss of power.
 - k. Actuator position on loss of control signal.
- 3. Schedule and design calculations for control valves and actuators.
 - a. Flow at Project design and minimum flow conditions.
 - b. Pressure-differential drop across valve at Project design flow condition.
 - c. Maximum system pressure-differential drop (pump close-off pressure) across valve at Project minimum flow condition.
 - d. Design and minimum control valve coefficient with corresponding valve position.
 - e. Maximum close-off pressure.
 - f. Leakage flow at maximum system pressure differential.
 - g. Torque required at worst case condition for sizing actuator.
 - h. Actuator selection indicating torque provided.
 - i. Actuator signal to control damper (on, close or modulate).
 - j. Actuator position on loss of power.
 - k. Actuator position on loss of control signal.
- 4. Schedule and design calculations for selecting flow instruments.
 - a. Instrument flow range.
 - b. Project design and minimum flow conditions with corresponding accuracy, control signal to transmitter, and output signal for remote control.
 - c. Extreme points of extended flow range with corresponding accuracy, control signal to transmitter, and output signal for remote control.
 - d. Pressure-differential loss across instrument at Project design flow conditions.
 - e. Where flow sensors are mated with pressure transmitters, provide information for each instrument separately and as an operating pair.

H. Sustainable Design Submittals:

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings:

- 1. Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved.
- 2. Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved.

B. Qualification Statements:

1. Systems Provider's Qualification Data:

- a. Resume of project manager assigned to Project.
- b. Resumes of application engineering staff assigned to Project.
- c. Resumes of installation and programming technicians assigned to Project.
- d. Resumes of service technicians assigned to Project.
- e. Brief description of past project including physical address, floor area, number of floors, building system cooling and heating capacity, and building's primary function.
- f. Description of past project DDC system, noting similarities to Project scope and complexity indicated.
- g. Names of staff assigned to past project that will also be assigned to execute work of this Project.
- h. Owner contact information for past project including name, phone number, and email address.
- i. Contractor contact information for past project including name, phone number, and email address.
- j. Architect[**and Engineer**] contact information for past project including name, phone number, and email address.

2. Manufacturer's qualification data.

3. Testing agency's qualification data.

C. Welding certificates.

D. Product Certificates:

1. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with ASHRAE 135.
2. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with LonWorks.

E. Test and Evaluation Reports:

1. Product Test Reports: For each product, for tests performed by [**manufacturer and witnessed by a qualified testing agency**].
2. Preconstruction Test Reports: For each separate test performed.

F. Source Quality-Control Submittals:

1. Source quality-control reports.

G. Field Quality-Control Submittals:

1. Field quality-control reports.

H. Sample warranty.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For DDC system.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
 - b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
 - c. As-built versions of submittal Product Data.
 - d. Names, addresses, email addresses, and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
 - e. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing set points and variables.
 - f. Programming manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
 - g. Engineering, installation, and maintenance manuals that explain how to do the following:
 - 1) Design and install new points, panels, and other hardware.
 - 2) Perform preventive maintenance and calibration.
 - 3) Debug hardware problems.
 - 4) Repair or replace hardware.
 - h. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.
 - i. Backup copy of graphic files, programs, and databases on electronic media.
 - j. List of recommended spare parts with part numbers and suppliers.
 - k. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
 - l. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
 - m. Licenses, guarantees, and warranty documents.
 - n. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
 - o. Owner training materials.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- ### A. Extra Stock Material: Furnish extra materials and parts to Owner that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- B. Include product manufacturers' recommended parts lists for proper product operation over **[Five]** -year period following warranty period. Parts list to be indicated for each year.
- C. Furnish parts, as indicated by manufacturer's recommended parts list, for product operation during **[Five]** -year period following warranty period.
- D. Furnish at least **[two]** quantity indicated of matching product(s) in Project inventory for each unique size and type.

1.8 QUALITY ASSURANCE

A. DDC System Manufacturer Qualifications:

- 1. Nationally recognized manufacturer of DDC systems and products.
- 2. DDC systems with similar requirements to those indicated for a continuous period of **[10]** years within time of bid.
- 3. DDC systems and products that have been successfully tested and in use on at least **[five]** past projects.
- 4. Having complete published catalog literature, installation, operation, and maintenance manuals for all products intended for use.
- 5. Having full-time in-house employees for the following:
 - a. Product research and development.
 - b. Product and application engineering.
 - c. Product manufacturing, testing, and quality control.
 - d. Technical support for DDC system installation training, commissioning, and troubleshooting of installations.
 - e. Owner operator training.

B. DDC System Provider Qualifications:

- 1. Authorized representative of, and trained by, DDC system manufacturer.
- 2. In-place facility located within of Project.
- 3. Demonstrate past experience with installation of DDC system products being installed for period within **[five]** consecutive years before time of bid.
- 4. Demonstrate past experience on **[five]** projects of similar complexity, scope, and value.
- 5. Demonstrate past experience of each **[person]** assigned to Project.
- 6. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
- 7. Service and maintenance staff assigned to support Project during warranty period.
- 8. Product parts inventory to support ongoing DDC system operation for a period of not less than **[five]** years after Substantial Completion.
- 9. DDC system manufacturer's backing to take over execution of the Work if necessary to comply with requirements indicated. Include Project-specific written letter, signed by manufacturer's corporate officer, if requested.

C. Testing Agency Qualifications: Member company of NETA.

- 1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

- D. Welding Qualifications: Qualify procedures and personnel in accordance with the following welding codes:
 - 1. AWS D1.1/D1.1M.
 - 2. AWS D1.2/D1.2M.
 - 3. AWS D1.3/D1.3M.
 - 4. AWS D1.4/D1.4M.
- E. Pipe and Pressure-Vessel Welding Qualifications: Qualify procedures and operators in accordance with ASME Boiler and Pressure Vessel Code.

1.9 MOCKUPS

- A. Build mockups to verify selections made under Sample submittals, to demonstrate aesthetic effects, to set quality standards for materials and execution, and to set quality standards for fabrication and installation.
 - 1. Build mockups of completed installation for areas as indicated on Drawings.
 - 2. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Owner specifically approves such deviations by Change Order.
 - 3. Subject to compliance with requirements, approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.10 PRECONSTRUCTION TESTING

- A. Preconstruction Testing Service: **[Engage]** a qualified testing agency to perform preconstruction testing on field mockups.
 - 1. Provide test assemblies representative of proposed materials and construction.
 - 2. Build laboratory mockups at testing agency facility; use personnel, materials, and methods of construction that will be used at Project site.
 - 3. Notify Architect **[seven]** days in advance of dates and times when laboratory mockups will be tested.
- B. Preconstruction Testing: Performed by a qualified testing agency on manufacturer's standard assemblies.

1.11 WARRANTY

- A. Special Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.
 - 1. Adjust, repair, or replace failures at no additional cost or reduction in service to Owner.
 - 2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.
 - a. Install updates only after receiving Owner's written authorization.

3. Perform warranty service during normal business hours and commence within **[24]** hours of Owner's warranty service request.
4. Warranty Period: **[Two]** year(s) from date of Substantial Completion.
 - a. For Gateway: **[Three]** -year parts and labor warranty for each.

PART 2 - PRODUCTS

2.1 DDC SYSTEM MANUFACTURERS

2.2 DDC SYSTEM DESCRIPTION

- A. Microprocessor-based monitoring and control including analog/digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices to achieve a set of predefined conditions.
 1. DDC system consisting of **[high-speed,]** peer-to-peer network of distributed DDC controllers **[, other network devices]**, operator interfaces, and software.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 WEB ACCESS

- A. DDC system to be **[web based]**.
 1. Web-Based Access to DDC System:
 - a. DDC system software based on server thin-client architecture, designed around open standards of web technology. DDC system server accessed using a web browser over DDC system network, using Owner's LAN, and remotely over Internet **[through Owner's LAN]**.
 - b. Intent of thin-client architecture is to provide operators complete access to DDC system via a web browser. No special software other than a web browser is required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.
 - c. Password-protected web access.

2.4 PERFORMANCE REQUIREMENTS

- A. ASME Compliance:
 1. DDC system for monitoring and controlling of HVAC systems.
- B. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.

- C. Delegated Design, Qualified Professional Engineer: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design DDC system to satisfy requirements indicated.
- D. Delegated Design, Qualified Professional: Engage a qualified professional to design DDC system to satisfy requirements indicated.
 - 1. System Performance Objectives:
 - a. DDC system manages HVAC systems.
 - b. DDC system operates HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
 - c. DDC system responds to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
 - d. DDC system operates while unattended by an operator and through operator interaction.
 - e. DDC system records trends and transactions of events and produces report information such as performance, energy, occupancies, and equipment operation.
- E. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths complying with ASTM E84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 - 1. Flame-Spread Index: **[25]** or less.
 - 2. Smoke-Developed Index: **[50]** or less.
- F. DDC System Speed:
 - 1. Response Time of Connected I/O:
 - a. Update AI point values connected to DDC system at least every **[five]** seconds for use by DDC controllers. Points used globally to also comply with this requirement.
 - b. Update BI point values connected to DDC system at least every **[five]** seconds for use by DDC controllers. Points used globally to also comply with this requirement.
 - c. AO points connected to DDC system to begin to respond to controller output commands within **[two]** second(s). Global commands to also comply with this requirement.
 - d. BO point values connected to DDC system to respond to controller output commands within **[two]** second(s). Global commands to also comply with this requirement.
 - 2. Display of Connected I/O:
 - a. Update and display analog point COV connected to DDC system at least every **[five]** seconds for use by operator.
 - b. Update and display binary point COV connected to DDC system at least every **[five]** seconds for use by operator.
 - c. Update and display alarms of analog and digital points connected to DDC system within **[15]** seconds of activation or change of state.
 - d. Update graphic display refresh within **[four]** seconds.

- e. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations to not exceed graphic refresh rate indicated.
- G. Network Bandwidth: Design each network of DDC system to include spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions. Minimum spare bandwidth as follows:
 - 1. Level 1 Networks: **[20]** .
 - 2. Level 2 Networks: **[20]** .
 - 3. Level 3 Networks: **[10]** .
- H. DDC System Data Storage:
 - 1. Include capability to archive not less than **[48]** consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends, and other information indicated.
 - 2. Local Storage:
 - a. Provide **[server]** with data storage indicated. Server(s) to use IT industry standard database platforms and be capable of functions described in "DDC Data Access" Paragraph.
 - 3. Cloud Storage:
 - a. Provide **[application-based]** **[and]** **[web browser]** interfaces to configure, upload, download, and manage data and to service plan with storage adequate to store all data for term indicated. Cloud storage uses IT industry standard database platforms and is capable of functions described in "DDC Data Access" Paragraph.
- I. DDC Data Access:
 - 1. When logged into the system, operator able to also interact with any DDC controllers connected to DDC system as required for functional operation of DDC system.
 - 2. Use for application configuration; for archiving, reporting, and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.
- J. Future Expandability:
 - 1. DDC system size is expandable to an ultimate capacity of at least **[1.25]** times total I/O points indicated.
 - 2. Design and install system networks to achieve ultimate capacity with only addition of DDC controllers, I/O, and associated wiring and cable. Design and install initial network infrastructure to support ultimate capacity without having to remove and replace portions of network installation.
 - 3. Operator interfaces installed initially do not require hardware and software additions and revisions for system when operating at ultimate capacity.

- K. Input Point Values Displayed Accuracy: Meet following end-to-end overall system accuracy, including errors associated with meter, sensor, transmitter, lead wire or cable, and analog to digital conversion.
1. Energy:
 - a. Thermal: Within [1] percent of reading.
 - b. Electric Power: Within [1] percent of reading.
 - c. Requirements indicated on Drawings for meters not supplied by utility.
 2. Flow:
 - a. Air: Within [2] percent of design flow rate.
 - b. Air (Terminal Units): Within [5] percent of design flow rate.
 - c. Fuel Oil: Within [2] percent of design flow rate.
 - d. Natural Gas: Within [2] percent of design flow rate.
 - e. Water: Within [2] percent of design flow rate.
 - f. Steam: Within [5] percent of design flow rate.
 3. Gas:
 - a. Carbon Dioxide: Within [50] ppm.
 - b. Carbon Monoxide: Within [5] percent of reading.
 - c. Oxygen: Within [5] percent of reading.
 - d. Refrigerant: Within [5] percent of reading.
 - e. VOCs: Within [5] percent of reading.
 4. Moisture (Relative Humidity):
 - a. Air: Within [5] [2] percent RH.
 - b. Space: Within [5] [2] percent RH.
 - c. Outdoor: Within [5] [2] percent RH.
 5. Level: Within [5] [2] percent of reading.
 6. Pressure:
 - a. Air, Ducts and Equipment: [1] percent of instrument [range] .
 - b. Space: Within [1] percent of instrument [range] .
 - c. Water: Within [1] percent of instrument [range].
 - d. Steam: Within [1] percent of instrument [range] [span].
 7. Speed: Within [5] percent of reading.
 8. Temperature, Dew Point:
 - a. Air: Within [1 deg F (0.5 deg C)] .
 - b. Space: Within [1 deg F (0.5 deg C)].
 - c. Outdoor: Within [3 deg F (1.5 deg C)] .
 9. Temperature, Dry Bulb:
 - a. Air: Within [1 deg F (0.5 deg C)] .

- b. Space: Within [1 deg F (0.5 deg C)] .
- c. Outdoor: Within [2 deg F (1 deg C)] .
- d. Chilled Water: Within [1 deg F (0.5 deg C)] .
- e. Condenser Water: Within [1 deg F (0.5 deg C)] .
- f. Heating Hot Water: Within [1 deg F (0.5 deg C)] .
- g. Energy Recovery Runaround Liquid: Within [1 deg F (0.5 deg C)] .
- h. Steam: Within [2 deg F (1 deg C)] [1 deg F (0.5 deg C)] .
- i. Temperature Difference: Within [0.1 deg F (0.05 deg C)] .
- j. Other Temperatures Not Indicated: Within [1 deg F (0.5 deg C)] .

10. Temperature, Wet Bulb:

- a. Air: Within [1 deg F (0.5 deg C)].
- b. Space: Within [1 deg F (0.5 deg C)].
- c. Outdoor: Within [2 deg F (1 deg C)].

11. Vibration: Within [5] percent of reading.

L. Precision of I/O Reported Values: Values reported in database and displayed to have following precision:

1. Current:

- a. Milliamperes: Nearest 1/100th of a milliampere.
- b. Amperes: Nearest 1/10th of an ampere up to 100 A; nearest ampere for 100 A and more.

2. Energy:

- a. Electric Power:
 - 1) Rate (Watts): Nearest 1/10th of a watt through 1000 W.
 - 2) Rate (Kilowatts): Nearest 1/10th of a kilowatt through 1000 kW; nearest kilowatt above 1000 kW.
 - 3) Usage (Kilowatt-Hours): Nearest kilowatt through 10,000 kW; nearest 10 kW between 10,000 and 100,000 kW; nearest 100 kW for above 100,000 kW.
- b. Fuel Oil (Usage): For gallons, nearest 1/10th of a gallon up to 100 gal.; nearest gallon for above 100 gal. (For liters, nearest 1/10th of a liter up to 1000 L; nearest liter for above 1000 L).
- c. Natural Gas (Usage): Nearest 1/10th of a unit (cubic feet, MCF, therm) up to 100 units; nearest unit for above 100 units (For MCM, nearest 1/10th of an MCM up to 1000 MCM; nearest MCM for above 1000 MCM).
- d. Thermal, Rate:
 - 1) Heating: For British thermal units per hour, nearest British thermal unit per hour up to 1000 Btu/h; nearest 10 Btu/h between 1000 and 10,000 Btu/h; nearest 100 Btu/h for above 10,000 Btu/h. For MBh, round to nearest MBh up to 1000 MBh; nearest 10 MBh between 1000 and 10,000 MBh; nearest 100 MBh above 10,000 MBh (For watts, nearest watt up to 1000 W; for

kilowatts, round to nearest kilowatt up to 1000 kW; nearest 10 kW between 1000 and 10 000 kW; nearest 100 kW for above 10 000 kW).

- 2) **Cooling:** For tons, nearest ton up to 1000 tons; nearest 10 tons between 1000 and 10,000 tons; nearest 100 tons above 10,000 tons (For watts, nearest watt up to 1000 W; for kilowatts, round to nearest kilowatt up to 1000 kW; nearest 10 kW between 1000 and 10 000 kW; nearest 100 kW for above 10 000 kW).

e. Thermal, Usage:

- 1) **Heating:** For British thermal unit, nearest British thermal unit up to 1000 Btu; nearest 10 Btu between 1000 and 10,000 Btu; nearest 100 Btu for above 10,000 Btu. For MBtu, round to nearest MBtu up to 1000 MBtu; nearest 10 MBtu between 1000 and 10,000 MBtu; nearest 100 MBtu above 10,000 MBtu (For watt-hours, nearest watt-hour up to 1000 Wh; for kilowatt-hours, round to nearest kilowatt-hour up to 1000 kWh; nearest 10 kWh between 1000 and 10 000 kWh; nearest 100 kWh for above 10 000 kWh).
- 2) **Cooling:** For ton-hours, nearest ton-hours up to 1000 ton-hours; nearest 10 ton-hours between 1000 and 10,000 ton-hours; nearest 100 tons above 10,000 tons (For watt-hours, nearest watt-hour up to 1000 Wh; for kilowatt-hours, round to nearest kilowatt-hour up to 1000 kWh; nearest 10 kWh between 1000 and 10 000 kWh; nearest 100 kWh for above 10 000 kWh).

3. Flow:

- a. **Air:** Nearest 1/10th of a cubic feet per minute through 100 cfm; nearest cubic feet per minute between 100 and 1000 cfm; nearest 10 cfm between 1000 and 10,000 cfm; nearest 100 cfm above 10,000 cfm (Nearest 1/10th of a liter per second through 100 L/s; nearest liter per second between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10 000 L/s; nearest 100 L/s above 10 000 L/s).
- b. **Fuel Oil:** Nearest 1/10th of a gallon per minute through 100 gpm; nearest gallon per minute between 100 and 1000 gpm (Nearest 1/10th of a liter per second through 100 L/s; nearest liter per second between 100 and 1000 L/s).
- c. **Natural Gas:** Nearest 1/10th of a cubic feet per hour through 100 cfh; nearest cubic feet per hour between 100 and 1000 cfh; nearest 10 cfh between 1000 and 10,000 cfh; nearest 100 cfh above 10,000 cfh (Nearest 1/100th of a cubic meter per hour through 100 cmh; nearest 1/10th cmh between 100 and 1000 cmh; nearest cubic meter per hour above 1000 cmh).
- d. **Water:** Nearest 1/10th of a gallon per minute through 100 gpm; nearest gallon per minute between 100 and 1000 gpm; nearest 10 gpm between 1000 and 10,000 gpm; nearest 100 gpm above 10,000 gpm (Nearest 1/10th of a liter per second through 100 L/s; nearest liter per second between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10 000 L/s; nearest 100 L/s above 10 000 L/s).
- e. **Steam:** Nearest 1/10th of a pound per hour through 100 lb/h; nearest pound per hour between 100 and 1000 lb/h; nearest 10 lb/h above 1000 lb/h (Nearest 1/10th of a liter per second through 100 L/s; nearest liter per second between 100 and 1000 L/s; nearest 10 L/s above 1000 L/s).

4. Gas:
 - a. Carbon Dioxide (ppm): Nearest ppm.
 - b. Carbon Monoxide (ppm): Nearest ppm.
 - c. Oxygen (Percentage): Nearest 1/10th of 1 percent.
 - d. Refrigerant (ppm): Nearest ppm.
 - e. Volatile Organic Compounds (ppm): Nearest ppm
5. Moisture (Relative Humidity):
 - a. Relative Humidity (Percentage): Nearest 1 percent.
6. Level: Nearest 1/100th of an inch through 10 inches; nearest 1/10 of an inch between 10 and 100 inches; nearest inch above 100 inches (Nearest 1/100th of a millimeter through 10 mm; nearest 1/10th of a millimeter between 10 and 100 mm; nearest millimeter above 100 mm).
7. Speed:
 - a. Rotation (rpm): Nearest 1 rpm.
 - b. Velocity: Nearest 1/10th of feet per minute through 100 fpm; nearest feet per minute between 100 and 1000 fpm; nearest 10 fpm above 1000 fpm (Nearest 1/100th of a meter per second through 10 m/s; nearest 1/10th of a meter per second above 10 m/s).
8. Position, Dampers and Valves (Percentage Open): Nearest 1 percent.
9. Pressure:
 - a. Air, Ducts and Equipment: Nearest 1/10th of an inch water closet (Nearest pascal up to 1000 Pa; nearest 10 Pa above 1000 Pa).
 - b. Space: Nearest 1/100th of an inch water closet (Nearest 1/10th of a pascal).
 - c. Steam: Nearest 1/10th of pounds per square inch gauge through 100 psig; nearest pounds per square inch gauge above 100 psig (Nearest kilopascal through 1000 kPa; nearest 10 kPa above 1000 kPa).
 - d. Water: Nearest 1/10 of a pound per square inch gauge through 100 psig; nearest pound per square inch gauge above 100 psig (Nearest kilopascal through 1000 kPa; nearest 10 kPa above 1000 kPa).
10. Temperature:
 - a. Air, Ducts and Equipment: Nearest 1/10th of a degree.
 - b. Outdoor: Nearest degree.
 - c. Space: Nearest 1/10th of a degree.
 - d. Chilled Water: Nearest 1/10th of a degree.
 - e. Condenser Water: Nearest 1/10th of a degree.
 - f. Heating Hot Water: Nearest degree.
 - g. Heat Recovery Runaround: Nearest 1/10th of a degree.
 - h. Steam: Nearest degree.
11. Vibration: Nearest 1/10th of an inch per second (Nearest 1/10th of a millimeter per second).
12. Voltage: Nearest 1/10 V up to 100 V; nearest volt above 100 V.

M. Control Stability: Control variables indicated within the following limits:

1. Flow:
 - a. Air, Ducts and Equipment, except Terminal Units: Within [5] percent of design flow rate.
 - b. Air, Terminal Units: Within [5] percent of design flow rate.
 - c. Water: Within [5] percent of design flow rate.
 - d. Steam: Within [5] percent of design flow rate.
2. Gas:
 - a. Carbon Dioxide: Within [50] ppm.
 - b. Carbon Monoxide: Within [5] percent of reading.
 - c. Oxygen: Within [5] percent of reading.
3. Moisture (Relative Humidity):
 - a. Air: Within [5] percent RH.
 - b. Space: Within [5] percent RH.
 - c. Outdoor: Within [5] percent RH.
4. Level: Within [5] percent of reading.
5. Pressure:
 - a. Air, Ducts and Equipment: [1] > percent of instrument [range] .
 - b. Space: Within [1] percent of instrument [range] .
 - c. Water: Within [1] percent of instrument [range].
 - d. Steam: Within [1] percent of instrument [range].
6. Temperature, Dew Point:
 - a. Air: Within [1 deg F (0.5 deg C)].
 - b. Space: Within [1 deg F (0.5 deg C)].
7. Temperature, Dry Bulb:
 - a. Air: Within [1 deg F (0.5 deg C)].
 - b. Space: Within [1 deg F (0.5 deg C)].
 - c. Chilled Water: Within [1 deg F (0.5 deg C)].
 - d. Condenser Water: Within [1 deg F (0.5 deg C)].
 - e. Heating Hot Water: Within [1 deg F (0.5 deg C)].
8. Temperature, Wet Bulb:
 - a. Air: Within [1 deg F (0.5 deg C)].
 - b. Space: Within [1 deg F (0.5 deg C)].

N. Environmental Conditions for Controllers, Gateways, and Routers:

1. Products to operate without performance degradation under ambient environmental temperature, pressure, and humidity conditions encountered for installed location.

- a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure to be internally insulated, electrically heated, cooled, and ventilated as required by product and application.
 2. Protect products with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. House products not available with integral enclosures complying with requirements indicated in protective secondary enclosures. Installed location dictates the following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: **[Type 12]**
 - b. Outdoors, Unprotected: **[Type 4X]**.
 - c. Indoors, Heated with Filtered Ventilation: **[Type 2]**
 - d. Indoors, Heated with Non-Filtered Ventilation: **[Type 2]** .
 - e. Indoors, Heated and Air-Conditioned: **[Type 1]**.
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: **[Type 12]**.
 - 2) Air-Moving Equipment Rooms: **[Type 12]**.
 - g. Localized Areas Exposed to Washdown: **[Type 4X]**.
 - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: **[Type 12]**.
 - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: **[Type 4X]**.
 - j. Hazardous Locations: Explosion-proof rating for condition.
- O. Environmental Conditions for Instruments and Actuators:
1. Instruments and actuators to operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - a. If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure is internally insulated, electrically heated[, **cooled**], and ventilated as required by instrument and application.
 2. Protect instruments, actuators, and accessories with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. House instruments and actuators not available with integral enclosures complying with requirements indicated in protective secondary enclosures. Installed location is to dictate the following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: **[Type 12]**
 - b. Outdoors, Unprotected: **[Type 4X]**.
 - c. Indoors, Heated with Filtered Ventilation: **[Type 2]**
 - d. Indoors, Heated with Non-Filtered Ventilation: **[Type 2]**.
 - e. Indoors, Heated and Air-conditioned: **[Type 1]**.
 - f. Mechanical Equipment Rooms:

- 1) Chiller and Boiler Rooms: [Type 12] .
- 2) Air-Moving Equipment Rooms: [Type 2]

- g. Localized Areas Exposed to Washdown: [Type 4X]
- h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: [Type 12]
- i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: [Type 4X]
- j. Hazardous Locations: Explosion-proof rating for condition.

P. DDC System Reliability:

1. Design, install, and configure DDC controllers, [gateways,] [routers,] to yield a MTBF of at least [40,000] hours, based on a confidence level of at least [90] percent. MTBF value includes any failure for any reason to any part of products indicated.
2. If required to comply with MTBF indicated, include DDC system and product redundancy to maintain DCC system, and associated systems and equipment being controlled, operational, and under automatic control.
3. See Drawings for critical systems and equipment that require a higher degree of DDC system redundancy than MTBF indicated.

Q. Electric Power Quality:

1. Power-Line Surges:

- a. Protect [susceptible] DDC system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.1 and IEEE C62.41.2.
- b. Do not use fuses for surge protection.
- c. Test protection in the normal mode and in the common mode, using the following two waveforms:
 - 1) 10-by-1000-microsecond waveform with a peak voltage of 1500 V and a peak current of 60 A.
 - 2) 8-by-20-microsecond waveform with a peak voltage of 1000 V and a peak current of 500 A.

2. Power Conditioning:

- a. Protect [susceptible] DDC system products connected to ac power circuits from irregularities and noise rejection. Characteristics of power-line conditioner are as follows:
 - 1) At 85 percent load, output voltage to not deviate by more than plus or minus 1 percent of nominal when input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.
 - 2) During load changes from zero to full load, output voltage to not deviate by more than [2] percent of nominal.
 - 3) Accomplish full correction of load switching disturbances within [five] cycles, and 95 percent correction within [two] cycles of onset of disturbance.

- 4) Total harmonic distortion to not exceed **[2]** percent at full load.
3. Ground Fault: Protect products from ground fault by providing suitable grounding. Products to not fail due to ground fault condition.
- R. Backup Power Source:
 1. Serve DDC system products that control HVAC systems and equipment served by a backup power source also from a backup power source.
- S. UPS:
 1. DDC system products powered by UPS units are to include the following:
 - a. Servers.
 - b. Gateways.
 - c. DDC controllers[, **except application-specific controllers**].
 - d. Desktop workstations.
 2. DDC system instruments [**and actuators**] powered by UPS units are to include the following:
 - a. Instruments: [**Where indicated on Drawings;**] where associated with the following systems controlled by DDC system:
 - b. Damper Actuators: [**Where indicated on Drawings;**] where associated with the following systems controlled by DDC system:
 - c. Valve Actuators: [**Where indicated on Drawings;**] where associated with the following systems controlled by DDC system:
- T. Continuity of Operation after Electric Power Interruption:
 1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems are to automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.5 PANEL-MOUNTED, MANUAL OVERRIDE SWITCHES

- A. Manual Override of Control Dampers:
 1. Include panel-mounted, two-position, selector switch for each automatic control damper being controlled by DDC controller.
 2. Label each switch with damper designation served by switch.
 3. Label switch positions to indicate either "Manual" or "Auto" control signal to damper.
 4. With switch in "Auto" position, control signal to damper actuator with control loop output signal from DDC controller.

5. With switch in "Manual" position, control signal to damper actuator at panel with either an integral or a separate switch to include local control.
 - a. For Binary Control Dampers: Manual two-position switch with "Close" and "Open" switch positions indicated. With switch in "Close" position, close damper. With switch in "Open" position, open damper.
 - b. For Analog Control Dampers: A gradual switch with "Close" and "Open" switch limits indicated. Operator switches knob to adjust damper to any position from close to open.
6. DDC controller to monitor and report position of each manual override selector switch. With switch placed in "manual" position, DDC controller to signal an override condition to alert operator that damper is under manual, not automatic, control.
7. Configure manual override switches to allow operator to manually operate damper while at panel without DDC controller **[installed] [and] [operational]**.
8. Terminal equipment including **[VAV units,] [fan-coil units,] [and] [unit heaters]** do not require manual override unless otherwise indicated by sequence of operation.

B. Manual Override of Control Valves:

1. Include panel-mounted, two-position, selector switch for each automatic control valve being controlled by DDC controller.
2. Label each switch with valve designation served by switch.
3. Label switch positions to indicate either "Manual" or "Auto" control signal to valve.
4. With switch in "Auto" position, control signal to valve actuator with a control loop output signal from DDC controller.
5. With switch in "Manual" position, control signal to valve actuator at panel with either an integral or a separate switch to include local control.
 - a. For Binary Control Valves: Manual two-position switch with "Close" and "Open" switch positions indicated. With switch in "Close" position, close valve. With switch in "Open" position, open valve.
 - b. For Analog Control Valves: A gradual switch with "Open" and "Close" switch limits indicated. Operator rotates switch knob to adjust valve to any position from close to open.
6. DDC controller to monitor and report position of each manual override selector switch. With switch placed in "manual" position, DDC controller to signal an override condition to alert operator that valve is under manual, not automatic, control.
7. Configure manual override switches to allow operator to manually operate valve while at panel without DDC controller **[installed] [and] [operational]**.
8. Terminal equipment including **[VAV units,] [fan-coil units,] [and] [unit heaters]** do not require manual override unless otherwise indicated by sequence of operation.

2.6 SYSTEM ARCHITECTURE

A. System architecture consisting of no more than **[two] [or] [three]** levels of LANs.

1. Level 2 LAN: Connect network controllers and operator workstations.

2. [Level 1] [or] [Level 2] LAN: Connect programmable application controllers to other programmable application controllers and to network controllers.
 3. [Level 2] [or] [Level 3] LAN: Connect application-specific controllers to [programmable application controllers and to network controllers].
- B. Minimum Data Transfer and Communication Speed:
1. LAN Connecting Operator Workstations and Network Controllers: [100] Mbps.
 2. LAN Connecting Programmable Application Controllers: [1000] kbps.
 3. LAN Connecting Application-Specific Controllers: [115,000] bps.
- C. Provide dedicated[**and separated**] DDC system LANs that are not shared with other building systems and tenant data and communication networks.
- D. Provide modular system architecture with inherent ability to expand to not less than [1.25] times system size indicated with no impact to performance indicated.
- E. Configure architecture to [eliminate] [or] [minimize] need to remove and replace existing network equipment for system expansion.
- F. Make number of LANs and associated communication transparent to operator. Configure all I/O points residing on any LAN to be capable of global sharing between all system LANs.
- G. Design system to eliminate dependence on any single device for system alarm reporting and control execution. Design each controller to operate independently by performing own control, alarm management, and historical data collection.
- H. Special Network Architecture Requirements:
1. Air-Handling Systems: For control applications of an air-handling system that consists of air-handling unit(s) and VAV terminal units, include a dedicated LAN of application-specific controllers serving VAV terminal units connected directly to controller that is controlling air-handling-system air-handling unit(s). Basically, create DDC system LAN that aligns with air-handling system being controlled.

2.7 DDC SYSTEM OPERATOR INTERFACES

- A. Operator Means of System Access: Operator able to access entire DDC system through any of multiple means including, but not limited to, the following:
1. Desktop and portable workstation with hardwired connection through LAN port.
 2. Portable operator terminal with hardwired connection through LAN port.
 3. Portable operator workstation with wireless connection through LAN router.
 4. Mobile device and application with secured wireless connection through LAN router or cellular data service.
 5. Remote connection through web access.
- B. Make access to system, regardless of operator means used, transparent to operator.

- C. Network Ports: For hardwired connection of desktop or portable workstation. Network port easily accessible, properly protected, clearly labeled, and installed at the following locations:
1. Each mechanical equipment room.
 2. Each boiler room.
 3. Each chiller room.
 4. Each outdoor on-grade yard and elevated platform with equipment connected to DDC system.
 5. Each different roof level with roof-mounted equipment connected to DDC system.
 6. Security system command center.
 7. Fire-alarm system command center.
- D. Desktop Workstations:
1. Connect [**Owner-furnished**] desktop workstation(s) to DDC system Level 1 LAN through a communications port directly on LAN or through a communications port on a DDC controller.
 2. Able to communicate with any device located on any DDC system LAN.
- E. Portable Workstations:
1. Connect [**Owner-furnished**] portable workstation(s) to DDC system Level 1 LAN through a communications port directly on LAN or through a communications port on a DDC controller.
 2. Able to communicate with any device located on any DDC system LAN.
 3. Connect to DDC system [**Level 2**] [**or**] [**Level 3**] LAN through a communications port on an application-specific controller, or a room temperature sensor connected to an application-specific controller.
 4. Connect to system through a wireless router connected to Level 1 LAN.
 5. Connect to system through a cellular broadband data service.
 6. Portable workstation able to communicate with any device connected to any system LAN regardless of point of physical connection to system.
 7. Monitor, program, schedule, adjust set points, and report capabilities of I/O connected anywhere in system.
 8. Have dynamic graphic displays that are identical to desktop workstations.
- F. POT:
1. Connect DDC controller through a communications port local to controller.
 2. Able to communicate with any DDC system controller that is directly connected [**or with LAN**] [**or connected to DDC system**].
- G. Mobile Device (Tablet and Smart Phone):
1. Connect Owner-furnished mobile devices to system through a wireless router connected to LAN[**and cellular data service**].
 2. Able to communicate with any DDC controller connected to DDC system using [**dedicated application**] [**and**] [**secure web access**].

H. Critical Alarm Reporting:

1. Send operator-selected critical alarms to notify operator of critical alarms that require immediate attention.
2. Send alarm notification to multiple recipients that are assigned for each alarm.
3. Notify recipients by any or all means, including email, text message, and prerecorded phone message to mobile and landline phone numbers.

I. Simultaneous Operator Use: Capable of accommodating up to [**five**] simultaneous operators that are accessing DDC system through any of operator interfaces indicated.

2.8 NETWORKS

A. Acceptable networks for connecting workstations, mobile devices, and network controllers include the following:

1. ATA 878.1, ARCNET.
2. CTA-709.1-D.
3. IP.
4. ISO/IEC/IEEE 8802-3, Ethernet.

B. Acceptable networks for connecting programmable application controllers include the following:

1. ATA 878.1, ARCNET.
2. CTA-709.1-D.
3. IP.
4. ISO/IEC/IEEE 8802-3, Ethernet.

C. Acceptable networks for connecting application-specific controllers include the following:

1. ATA 878.1, ARCNET.
2. CTA-709.1-D.
3. TIA 485-A.
4. IP.
5. ISO/IEC/IEEE 8802-3, Ethernet.

2.9 NETWORK COMMUNICATION PROTOCOL

A. Use network communication protocol(s) that are open to Owner and available to other companies for use in making future modifications to DDC system.

B. ASHRAE 135 Protocol:

1. Use ASHRAE 135 communication protocol as sole and native protocol used throughout entire DDC system.
2. DDC system to not require use of gateways except to integrate HVAC equipment and other building systems and equipment; not required to use ASHRAE 135 communication protocol.

3. If used, gateways to connect to DDC system using ASHRAE 135 communication protocol and Project object properties and read/write services indicated by interoperability schedule.
4. Use operator workstations, controllers, and other network devices that are tested and listed by BTL.

C. CTA-709.1-D Protocol:

1. Open implementation of LonWorks technology using CTA 709.1-D communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for communication throughout DDC system.
2. Use LNS for all network management including addressing and binding of network variables.
 - a. Submit final LNS database with Project closeout submittals.
 - b. All devices are to be online and commissioned into LNS database.
3. Use CTA-709.1-D protocol for all connected device. Install so SCPT output from any node on network can be bound to any other node in the domain.

D. Industry Standard Protocols:

1. Use any one or a combination of the following industry standard protocols for network communication while complying with other DDC system requirements indicated:
 - a. ASHRAE 135.
 - b. CTA-709.1-D.
 - c. Modbus Application Protocol Specification V1.1b3.
2. Operator workstations [**and network controllers**] are to communicate through [**ASHRAE 135**] [**or**] [**CTA-709.1-D**] protocol.
3. Provide portions of DDC system networks using ASHRAE 135 communication protocol as an open implementation of network devices complying with ASHRAE 135. Use network devices that are tested and listed by BTL.
4. Provide portions of DDC system networks using CTA-709.1-D communication protocol as an open implementation of LonWorks technology using CTA-709.1-D communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for DDC system.
5. Provide portions of DDC system networks using Modbus Application Protocol Specification V1.1b3 communication protocol as an open implementation of network devices and technology complying with Modbus Application Protocol Specification V1.1b3.
6. Use gateways to connect networks and network devices with different protocols.

2.10 DDC SYSTEM WIRELESS NETWORKS

- A. Use [**Zigbee**] [**or**] [**an open industry standard and technology used by multiple DDC system manufacturers**] technology to create a wireless mesh network to provide wireless connectivity for network devices at multiple system levels including communications from programmable application controllers and application-specific controllers to temperature

sensors and from network controllers to programmable application controllers and application-specific controllers.

- B. Design and install wireless networks to comply with DDC system performance requirements indicated using wireless network devices that can co-exist on same network with hardwired devices.
- C. Provide hardwired controllers capable of retrofitting to wireless devices with no special software.
- D. Provide a wireless coordinator for wireless interface between programmable application controllers, application-specific controllers, and network controllers.
- E. Wireless Coordinators:
 - 1. Use for initiation and formation of each wireless mesh network.
 - 2. Use direct-sequence spread spectrum RF technology.
 - 3. Operate on 2.4 GHz ISM Band.
 - 4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
 - 5. FCC compliant to 47 CFR 15, Subpart B, Class A.
 - 6. Operate as a bidirectional transceiver with sensors and routers to confirm and synchronize data transmission.
 - 7. Capable of communication with sensors and routers up to a maximum distance of **250 ft. (76 m)** in line of sight.
 - 8. Include visual indicators to provide diagnostic information required for operator verification of operation.
- F. Wireless Routers:
 - 1. Use wireless routers with any controller to provide a wireless interface to a network controller, through a wireless coordinator.
 - 2. Use direct-sequence spread spectrum RF technology.
 - 3. Operate on 2.4 GHz ISM Band.
 - 4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
 - 5. FCC compliant to 47 CFR 15, Subpart B, Class A.
 - 6. Operate as a bidirectional transceiver with other mesh network devices to ensure network integrity.
 - 7. Capable of communication with other mesh network devices at a maximum distance of **250 ft. (76 m)** in line of sight.
 - 8. Include indication for use in commissioning and troubleshooting.
- G. Wireless Temperature Sensors:
 - 1. Wireless temperature sensors to sense and transmit room temperatures, temperature set point, room occupancy notification, and low battery condition to an associated router.
 - 2. Use direct-sequence spread spectrum RF technology.
 - 3. Operate on 2.4 GHz ISM Band.
 - 4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
 - 5. FCC compliant to 47 CFR 15, Subpart B, Class A.
 - 6. Include set-point adjustment between [**55 to 85 deg F (13 to 30 deg C)**] .

7. Configure so multiple sensors can report to a router connected to DDC controller for averaging or high and low selection.

H. One-to-One Wireless Network Receivers:

1. One-to-one wireless receivers receive wireless RF signals containing temperature data from multiple wireless room temperature sensors and communicate information to programmable application controllers or application-specific controllers.
 - a. Use direct-sequence spread spectrum RF technology.
 - b. Operate on 2.4 GHz ISM Band.
 - c. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
 - d. FCC compliant to 47 CFR 15, Subpart B, Class A.
 - e. Operate as a bidirectional transceiver with sensors to confirm and synchronize data transmission.
 - f. Capable of communication up to a distance of **200 ft. (61 m)**.
 - g. Include visual indication of the following:
 - 1) Power.
 - 2) Receiver activity.
 - 3) Wireless RF transmission from wireless sensors.
 - 4) No transmission, weak signal, adequate signal, or excellent signal.

I. One-to-One Wireless Network Sensors:

1. One-to-one wireless sensors sense and report room temperatures to one-to-one receiver.
 - a. Use direct-sequence spread spectrum RF technology.
 - b. Operate on 2.4 GHz ISM Band.
 - c. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
 - d. FCC compliant to 47 CFR 15, Subpart B, Class A.
 - e. Include set-point adjustment between **55 to 85 deg F (13 to 30 deg C)**.

2.11 DESKTOP WORKSTATIONS

- A. Description: A tower or all-in-one computer designed for normal use at a single, semipermanent location.
- B. Performance Requirements:
 1. May dictate equipment exceeding minimum requirements indicated.
 2. ENERGY STAR compliant.
- C. Personal Computer:
 1. **<latest technology with maximum available capacity>**.
 2. Optical Read and Write Drive:

- a. <latest technology with maximum available capacity>.
3. Video Card:
 - a. <latest technology with maximum available capacity>.
4. Sound Card:
 - a. <latest technology with maximum available capacity>.
5. Network Interface Card: Include card with connection, as applicable.
 - a. 10-100-1000 base TX Ethernet with RJ-45 connector port.
 - b. 100 base FX Ethernet with SC or ST port.
- D. Wireless Ethernet, 802.11 ac:
 1. Optical Modem: Full duplex link for connection to optical fiber cable provided.
 2. I/O Ports:
 - a. Two USB 3.0 ports on front panel, six on back panel, and three internal on motherboard.
 - b. One serial port.
 - c. One parallel port.
 - d. Two PS/2 ports.
 - e. One RJ-45.
 - f. One stereo line-in and headphone/line-out on back panel.
 - g. One microphone and headphone connector on front panel.
 - h. One IEEE 1394 on front and back panel with PCI-e card.
 - i. One ESATA port on back panel.
 3. Battery: Life of at least three years to maintain system clock/calendar and ROM, at a minimum.
- E. Keyboard:
 1. 101 enhanced keyboard.
 2. Full upper- and lowercase ASCII keyset, numeric keypad, dedicated cursor control keypad, and 12 programmable function keys.
 3. Wireless operation within up to 72 inches (1800 mm) in front of workstation.
- F. Pointing Device:
 1. Two- or three-button mouse.
 2. Wireless operation within up to 72 inches (1800 mm) in front of workstation.
- G. Flat Panel Display Monitor:
 - a. <latest technology with maximum available capacity>
- H. Speakers:
 1. Two, with individual controls for volume, bass and treble.
 2. Signal to Noise Ratio: At least 65 dB.
 3. Power: At least 4 W per speaker/channel.

4. Magnetic shielding to prevent distortion on the video monitor.

- I. I/O Cabling: Include applicable cabling to connect I/O devices.

2.12 PORTABLE WORKSTATIONS

- A. Description: A self-contained computer designed to allow for normal use in different locations and conditions.

- B. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
2. ENERGY STAR compliant.
3. Hardware and software to support local down-loading to DDC controllers.
4. Data transfer rate to DDC controller is to be at network speed.

- C. Processor:

- a. **<latest technology with maximum available capacity>.**

2. Video Card:

- a. **<latest technology with maximum available capacity>.**

- D. I/O Ports:

1. Serial port.
2. Shared port for external keyboard or mouse.
3. Four USB 3.0 ports.
4. Ethernet port.
5. HDMI port.
6. IEEE 1394 port.

- E. Battery:

1. Capable of supporting operation of portable workstation for a minimum of [8] hours.
2. Battery life of at least three years.
3. Battery charge time of less than three hours.
4. Spare Battery(ies). [Two].

- F. Keyboard:

1. 85-key [**backlit**] keyboard.
2. Full upper- and lowercase ASCII keyset.

- G. Integral Pointing Device: Touchpad with two buttons. Gesture enabled.

- H. Display:

1. **<latest technology with maximum available capacity>.**

I. Network Interfaces:

1. Network Interface Card: Include card with connection, as application.
 - a. 10-100-1000 base TX Ethernet with RJ-45 connector port.
 - b. 100 base FX Ethernet with SC or ST port.
2. Wireless:
 - a. Internal with integrated antenna, capable of supporting WiFi standards 802.11 a/b/g/n.

J. Digital Video Disc Rewrite Recorder (DVD+/-RW):

1. Compatible with DVD discs and data, audio, recordable, and rewritable compact discs.
 - a. <latest technology with maximum available capacity>.

K. Accessories:

1. Nylon carrying case.
2. Docking station.
3. Mobile broadband card.
4. Wireless optical mouse.
5. [GB] [TB] portable hard drive.
6. Light-sensitive web cam and noise-cancelling digital array microphone.
7. Category 6a patch cable..
8. HDMI cable.

2.13 PORTABLE OPERATOR TERMINALS

- A. Description: Handheld device with integral keypad or touch screen operator interface.
- B. Display: Multiple lines of text display for use in operator interaction with DDC system.
- C. Cable: Flexible [coiling] cable, at least 36 inches (900 mm) long, with a plug-in jack for connection to DDC controllers, network ports, or instruments with an integral LAN port. As an alternative to hardwired connection, POTs may be accessible to DDC controllers through a wireless network connection.
- D. Power POTs through network connection.
- E. Connection of POTs to DDC system to not interrupt or interfere with normal network operation in any way, prevent alarms from being transmitted, or preclude central initiated commands and system modification.
- F. POTs to give operator ability to do the following:
 1. Display and monitor BI point status.
 2. Change BO point set point (on or off, open or closed).
 3. Display and monitor analog point values.
 4. Change analog control set points.

5. Command a setting of AO point.
6. Display and monitor I/O point in alarm.
7. Add a new or delete an existing I/O point.
8. Enable and disable I/O points, initiators, and programs.
9. Display and change time and date.
10. Display and change time schedules.
11. Display and change run-time counters and run-time limits.
12. Display and change time and event initiation.
13. Display and change control application and DDC parameters.
14. Display and change programmable offset values.
15. Access DDC controller initialization routines and diagnostics.

2.14 SERVERS

- A. Description: x86-based permanently installed computer used for client-server computing.
- B. Mounting: [**Rack**].
- C. Power: [**Dual**] power supply, minimum [**300**] W.
- D. Performance Requirements:
 1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
 2. ENERGY STAR compliant.
 - a. <**latest technology with maximum available capacity**>.
 3. Redundant Array of Independent Discs: [**Two**] configuration.
 4. Drive Bays: Eight at **2.5 inches (65 mm)** or eight at **3.5 inches (90 mm)**.
 5. Hard-Drive Storage: [**Two**] drives each with <**maximum**> [**GB**] [**TB**] storage and nominal rotational speed of 7200 rpm.
 6. Network Interface: [**Dual-port gigabit Ethernet**] [**Optical fiber**].
 7. DVD +RW drive.
 8. Color, flat-screen display with <**10 inches (mm)**> diagonal viewable area.
 9. Keyboard and mouse.
 10. Next-day on-site warranty for [**three**] -year period following Substantial Completion.
- E. Servers are to include the following:
 1. Full-feature backup server (server and backup minimum requirement).
 2. Software licenses.
 3. Cable installation between server(s) and network.
- F. Web Server:
 1. If required to be separate, include web server hardware and software to match, except backup server is not required.
 2. Firewalls between server web and networks.
 3. Password protection for access to server from web server.
 4. Cable installation between the server(s) and building Ethernet network.

- G. Power each server through a [**dedicated**]UPS unit.

2.15 PRINTERS

A. Color Laser Printer:

1. [**<latest technology with maximum available capacity>**].
2. Complies with ENERGY STAR requirements.
3. Capable of handling letter- and legal-size paper and overhead transparencies.
4. Two-sided printing.

2.16 SYSTEM SOFTWARE

A. System Software Minimum Requirements:

1. Real-time multitasking and multiuser [**64**]-bit operating system that allows concurrent multiple operator workstations operating and concurrent execution of multiple real-time programs and custom program development.
2. Operating system capable of operating DOS and Microsoft Windows applications.
3. Database management software to manage all data on an integrated and non-redundant basis. Additions and deletions to database are to be without detriment to existing data. Include cross linkages so no data required by a program can be deleted by an operator until that data have been deleted from respective programs.
4. Network communications software to manage and control multiple network communications to provide exchange of global information and execution of global programs.
5. Operator interface software to include day-to-day operator transaction processing, alarm and report handling, operator privilege level and data segregation control, custom programming, and online data modification capability.
6. Scheduling software to schedule centrally based time and event, temporary, and exception day programs.

B. Operator Interface Software:

1. Minimize operator training through use of English language prorating and English language point identification.
2. Minimize use of a typewriter-style keyboard through use of a pointing device similar to a mouse.
3. Make operator sign-off a manual operation or, if no keyboard or mouse activity takes place, an automatic sign-off.
4. Make automatic sign-off period programmable from one to 60 minutes in one-minute increments on a per operator basis.
5. Record operator sign-on and sign-off activity and send to printer.
6. Security Access:
 - a. Use password control for operator access to DDC system.
 - b. Assign an alphanumeric password (field assignable) to each operator.
 - c. Grant operators access to DDC system by entry of proper password.
 - d. Use same operator password regardless of which computer or other operator interface means are used.

- e. Automatically update additions or changes made to passwords.
 - f. Assign each operator an access level to restrict access to data and functions the operator is cable of performing.
 - g. Provide software with at least five access levels.
 - h. Assign each menu item an access level so that a one-for-one correspondence between operator assigned access level(s) and menu item access level(s) is required to gain access to menu item.
 - i. Display menu items to operator with those capable of access highlighted. Make menu and operator access level assignments online programmable and under password control.
7. Data Segregation:
- a. Include data segregation for control of specific data routed to a workstation, to an operator or to a specific output device, such as a printer.
 - b. Include at least [32] segregation groups.
 - c. Make segregation groups selectable such as "fire points," "fire points on second floor," "space temperature points," "HVAC points," and so on.
 - d. Make points assignable to multiple segregation groups. Display and output of data to printer or monitor is to occur where there is a match of operator or peripheral segregation group assignment and point segregations.
 - e. Make alarms displayed and printed at each peripheral to which segregation allows, but only those operators assigned to peripheral and having proper authorization level will be allowed to acknowledge alarms.
 - f. Assign operators and peripherals to multiple segregation groups and make all assignments online programmable and under password control.
8. Operators able to perform commands including, but not limited to, the following:
- a. Start or stop selected equipment.
 - b. Adjust set points.
 - c. Add, modify, and delete time programming.
 - d. Enable and disable process execution.
 - e. Lock and unlock alarm reporting for each point.
 - f. Enable and disable totalization for each point.
 - g. Enable and disable trending for each point.
 - h. Override control loop set points.
 - i. Enter temporary override schedules.
 - j. Define holiday schedules.
 - k. Change time and date.
 - l. Enter and modify analog alarm limits.
 - m. Enter and modify analog warning limits.
 - n. View limits.
 - o. Enable and disable demand limiting.
 - p. Enable and disable duty cycle.
 - q. Display logic programming for each control sequence.
9. Reporting:
- a. Generated automatically and manually.
 - b. Sent to displays, printers and disc files.

c. Types of Reporting:

- 1) General listing of points.
- 2) List points currently in alarm.
- 3) List of off-line points.
- 4) List points currently in override status.
- 5) List of disabled points.
- 6) List points currently locked out.
- 7) List of items defined in a "Follow-Up" file.
- 8) List weekly schedules.
- 9) List holiday programming.
- 10) List of limits and deadbands.

10. Summaries: For specific points, for a logical point group, for an operator selected group(s), or for entire system without restriction due to hardware configuration.

C. Graphic Interface Software:

1. Include a full interactive graphical selection means of accessing and displaying system data to operator. Include at least five levels with the penetration path operator assignable (for example, site, building, floor, air-handling unit, and supply temperature loop). Native language descriptors assigned to menu items are to be operator defined and modifiable under password control.
2. Include a hierarchical-linked dynamic graphic operator interface for accessing and displaying system data and commanding and modifying equipment operation. Interface is to use a pointing device with pull-down or penetrating menus, color, and animation to facilitate operator understanding of system.
3. Include at least 10 levels of graphic penetration with the hierarchy operator assignable.
4. Make descriptors for graphics, points, alarms, and such modifiable through operator's workstation under password control.
5. Make graphic displays online user definable and modifiable using the hardware and software provided.
6. Make data displayed within a graphic assignable regardless of physical hardware address, communication, or point type.
7. Make graphics online programmable and under password control.
8. Make points assignable to multiple graphics where necessary to facilitate operator understanding of system operation.
9. Graphics to also contain software points.
10. Penetration within a graphic hierarchy is to display each graphic name as graphics are selected to facilitate operator understanding.
11. Provide a back-trace feature to permit operator to move upward in the hierarchy using a pointing device. Back trace to show all previous penetration levels. Include operator with option of showing each graphic full-screen size with back trace as horizontal header or by showing a "stack" of graphics, each with a back trace.
12. Display operator accessed data on the monitor.
13. Provide operator with ability to select further penetration using pointing device to click on a site, building, floor, area, equipment, and so on. Display defined and linked graphic below that selection.
14. Include operator with means to directly access graphics without going through penetration path.
15. Make dynamic data assignable to graphics.

16. Display points (physical and software) with dynamic data provided by DDC system with appropriate text descriptors, status or value, and engineering unit.
17. Use color, rotation, or other highly visible means, to denote status and alarm states. Make colors variable for each class of points, as chosen by operator.
18. Provide dynamic points with operator adjustable update rates on a per point basis from [one] second to over a [minute].
19. For operators with appropriate privilege, command points directly from display using pointing device.
 - a. For an analog command point such as set point, display current conditions and limits so operator can position new set point using pointing device.
 - b. For a digital command point such as valve position, show valve in current state such as open or closed so operator could select alternative position using pointing device.
 - c. Include a keyboard equivalent for those operators with that preference.
20. Give operator ability to split or resize viewing screen into quadrants to show one graphic on one quadrant of screen and other graphics or spreadsheet, bar chart, word processing, curve plot, and other information on other quadrants on screen. This feature allows real-time monitoring of one part of system while displaying other parts of system or data to better facilitate overall system operation.
21. Help Features:
 - a. Online context-sensitive help utility to facilitate operator training and understanding.
 - b. Bridge to further explanation of selected keywords and contain text and graphics to clarify system operation.
 - 1) If help feature does not have ability to bridge on keywords for more information, provide a complete set of user manuals in an indexed word-processing program, which runs concurrently with operating system software.
 - c. Available for Every Menu Item:
 - 1) Index items for each system menu item.
22. Provide graphic generation software to allow operator ability to add, modify, or delete system graphic displays.
 - a. Include libraries of symbols depicting HVAC symbols such as fans, coils, filters, dampers, valves pumps, and electrical symbols[**similar to those indicated**].
 - b. Use a pointing device in conjunction with a drawing program to allow operator to perform the following:
 - 1) Define background screens.
 - 2) Define connecting lines and curves.
 - 3) Locate, orient, and size descriptive text.
 - 4) Define and display colors for all elements.
 - 5) Establish correlation between symbols or text and associated system points or other displays.

D. Project-Specific Graphics: Graphics documentation including, but not limited to, the following:

1. Site plan showing each building, and additional site elements, which are being controlled or monitored by DDC system.
2. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:
 - a. Room layouts with room identification and name.
 - b. Locations and identification of all monitored and controlled HVAC equipment and other equipment being monitored and controlled by DDC system.
 - c. Location and identification of each hardware point being controlled or monitored by DDC system.
3. Control schematic for each of following, including a graphic system schematic representation[, **similar to that indicated on Drawings,**] with point identification, set point and dynamic value indication[, **sequence of operation**] [**and**] [**control logic diagram**].
4. Graphic display for each piece of equipment connected to DDC system through a data communications link. Include dynamic indication of all points associated with equipment.
5. DDC system network riser diagram that shows schematic layout for entire system including all networks and all controllers, [**gateways**] [**operator workstations**] [**and**] [**other network devices**].

E. Customizing Software:

1. Software to modify and tailor DDC system to specific and unique requirements of equipment installed, to programs implemented and to staffing and operational practices planned.
2. Online modification of DDC system configuration, program parameters, and database using menu selection and keyboard entry of data into preformatted display templates.
3. At a minimum, include the following modification capability:
 - a. Operator Assignment: Designation of operator passwords, access levels, point segregation, and auto sign-off.
 - b. Peripheral Assignment: Assignment of segregation groups and operators to consoles and printers, designation of backup workstations and printers, designation of workstation header points, and enabling and disabling of print-out of operator changes.
 - c. System Configuration and Diagnostics; Communications and peripheral port assignments, DDC controller assignments to network, DDC controller enable and disable, assignment of command trace to points, and application programs and initiation of diagnostics.
 - d. System Text Addition and Change: English or native language descriptors for points, segregation groups and access levels and action messages for alarms, run time, and trouble condition.
 - e. Time and Schedule Change: Time and date set, time and occupancy schedules, exception and holiday schedules, and daylight-savings time schedules.
 - f. Point related change capability is to include the following:
 - 1) System and point enable and disable.
 - 2) Run-time enable and disable.

- 3) Assignment of points to segregation groups, calibration tables, lockout, and run time and to a fixed I/O value.
 - 4) Assignment of alarm and warning limits.
- g. Application program change capability is to include the following:
- 1) Enable and disable of software programs.
 - 2) Programming changes.
 - 3) Assignment of comfort limits, global points, time and event initiators, time and event schedules and enable and disable time and event programs.
4. Provide software to allow operator ability to add points, or groups of points, to DDC system and to link them to energy optimization and management programs. Make additions and modifications online programmable using operator workstations, downloaded to other network devices and entered into their databases. After verification of point additions and associated program operation, upload and record database on hard drive and disc for archived record.
 5. Include high-level language programming software capability for implementation of custom DDC programs. Include a compiler, linker, and up- and down-load capability.
 6. Include a library of DDC algorithms, intrinsic control operators, arithmetic, logic, and relational operators for implementation of control sequences. Also include, at a minimum, the following:
 - a. Proportional control (P).
 - b. Proportional plus integral (PI).
 - c. Proportional plus integral plus derivative (PID).
 - d. Adaptive and intelligent self-learning control.
 - 1) Algorithm monitors loop response to output corrections and adjust loop response characteristics in accordance with time constant changes imposed.
 - 2) Algorithm operates in a continuous self-learning manner and retains in memory a stored record of system dynamics so that on system shut down and restart, learning process starts from where it left off.
 7. Fully implemented intrinsic control operators including sequence, reversing, ratio, time delay, time of day, highest select AO, lowest select AO, analog controlled digital output, analog control AO, and digitally controlled AO.
 8. Logic operators such as "And," "Or," "Not," and others that are part of a standard set available with a high-level language.
 9. Arithmetic operators such as "Add," "Subtract," "Multiply," "Divide," and others that are part of a standard set available with a high-level language.
 10. Relational operators such as "Equal to," "Not Equal to," "Less Than," "Greater Than," and others that are part of a standard set available with a high-level language.

F. Alarm Handling Software:

1. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers[, gateways] [**and other network devices**].
2. Include first in, first out handling of alarms in accordance with alarm priority ranking, with most critical alarms first, and with buffer storage in case of simultaneous and multiple alarms.

3. Make alarm handling active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system.
4. Alarms display is to include the following:
 - a. Indication of alarm condition such as "Abnormal Off," "Hi Alarm," and "Low Alarm."
 - b. "Analog Value" or "Status" group and point identification with native language point descriptor such as "Space Temperature, Building 110, 2nd Floor, Room 212."
 - c. Discrete per point alarm action message, such as "Call Maintenance Dept. Ext-5561."
 - d. Include extended message capability to allow assignment and printing of extended action messages. Capability is to be operator programmable and assignable on a per point basis.
5. Direct alarms to appropriate operator workstations, printers, and individual operators by privilege level and segregation assignments.
6. Send email alarm messages to designated operators.
7. Send email, page, text, and voice messages to designated operators for critical alarms.
8. Categorize and process alarms by class.
 - a. Class 1:
 - 1) Associated with fire, security, and other extremely critical equipment monitoring functions; have alarm, trouble, return to normal, and acknowledge conditions printed and displayed.
 - 2) Unacknowledged alarms to be placed in unacknowledged alarm buffer.
 - 3) All conditions make an audible alarm sound and require individual acknowledgment to silence audible sound.
 - b. Class 2:
 - 1) Critical, but not life-safety related, and processed same as Class 1 alarms, except do not require individual acknowledgment.
 - 2) Acknowledgement may be through a multiple alarm acknowledgment.
 - c. Class 3:
 - 1) General alarms; printed, displayed, and placed in unacknowledged alarm buffer queues.
 - 2) Configure so each new alarm received makes an audible alarm sound that are silenced by "acknowledging" alarm or by pressing a "silence" key.
 - 3) Make acknowledgement of queued alarms either on an individual basis or through a multiple alarm acknowledgment.
 - 4) Print alarms returning to normal condition without an audible alarm sound or require acknowledgment.
 - d. Class 4:
 - 1) Routine maintenance or other types of warning alarms.

- 2) Alarms to be printed only, with no display, no audible sound and no acknowledgment required.
9. Include an unacknowledged alarm indicator on display to alert operator that there are unacknowledged alarms in system. Operator able to acknowledge alarms on an individual basis or through a multiple alarm acknowledge key, depending on alarm class.
 10. To ensure that no alarm records are lost, make it possible to assign a backup printer to accept alarms in case of failure of primary printer.
- G. Reports and Logs:
1. Include reporting software package that allows operator to select, modify, or create reports using DDC system I/O point data available.
 2. Setup each report so data content, format, interval, and date are operator definable.
 3. Sample and store report data on DDC controller, within storage limits of DDC controller, and then uploaded to archive on **[workstation]** **[server]** for historical reporting.
 4. Make it possible for operators to obtain real-time logs of all I/O points by type or status, such as alarm, point lockout, or normal.
 5. Store reports and logs on **[workstations]** **[and]** **[servers]** hard drives in a format that is readily accessible by other standard software applications, including spreadsheets and word processing.
 6. Make reports and logs readily printable and set to be print either on operator command or at a specific time each day.
- H. Standard Reports: Provide standard DDC system reports with operator ability to customize reports later.
1. All I/O: With current status and values.
 2. Alarm: All current alarms, except those in alarm lockout.
 3. Disabled I/O: All I/O points that are disabled.
 4. Alarm Lockout I/O: All I/O points in alarm lockout, whether manual or automatic.
 5. Alarm Lockout I/O in Alarm: All I/O in alarm lockout that are currently in alarm.
 6. Logs:
 - a. Alarm history.
 - b. System messages.
 - c. System events.
 - d. Trends.
- I. Custom Reports: Operator able to easily define and prepare any system data into a daily, weekly, monthly, annual, or other historical report. Reports to include a title with time and date stamp.
- J. Tenant Override Reports: Prepare Project-specific reports.
1. Daily report showing total time in hours that each tenant has requested after-hours HVAC.
 2. Weekly report showing daily total time in hours that each tenant has requested after-hours HVAC.
 3. Monthly report showing daily total time in hours that each tenant has requested after-hours HVAC.

4. Annual summary report that shows after-hours HVAC usage on a monthly basis.
- K. HVAC Equipment Reports: Prepare Project-specific reports.
1. Chiller Report: Daily report showing operating conditions of each chiller in accordance with ASHRAE 147 including, but not limited to, the following:
 - a. Chilled-water entering temperature.
 - b. Chilled-water leaving temperature.
 - c. Chilled-water flow rate.
 - d. Chilled-water inlet and outlet pressures.
 - e. Evaporator refrigerant pressure and temperature.
 - f. Condenser refrigerant pressure and liquid temperature.
 - g. Condenser-water entering temperature.
 - h. Condenser-water leaving temperature.
 - i. Condenser-water flow rate.
 - j. Refrigerant levels.
 - k. Oil pressure and temperature.
 - l. Oil level.
 - m. Compressor refrigerant discharge temperature.
 - n. Compressor refrigerant suction temperature.
 - o. Addition of refrigerant.
 - p. Addition of oil.
 - q. Vibration levels or observation that vibration is not excessive.
 - r. Motor amperes per phase.
 - s. Motor volts per phase.
 - t. Refrigerant monitor level (PPM).
 - u. Purge exhaust time or discharge count.
 - v. Ambient temperature (dry bulb and wet bulb).
 - w. Date and time logged.
- L. Utility Reports: Prepare Project-specific reports.
1. Electric Report:
 - a. Include weekly report showing daily electrical consumption and peak electrical demand with time and date stamp for each meter.
 - b. Include monthly report showing the daily electrical consumption and peak electrical demand with time and date stamp for each meter.
 - c. Include annual report showing monthly electrical consumption and peak electrical demand with time and date stamp for each meter.
 - d. For each weekly, monthly, and annual report, include sum total of submeters combined by load type, such as lighting, receptacles, and HVAC equipment showing daily electrical consumption and peak electrical demand.
 - e. For each weekly, monthly, and annual report, include sum total of all submeters in building showing electrical consumption and peak electrical demand.
 2. Natural Gas Report:
 - a. Include weekly, monthly, and annual report showing daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.

- b. For each weekly, monthly, and annual report, include sum total of submeters combined by load type, such as boilers and service water heaters showing daily natural gas consumption and peak natural gas demand.
 - c. For each weekly, monthly, and annual report, include sum total of all submeters in building showing natural gas consumption and peak natural gas demand.
 - 3. Service Water Report:
 - a. Include weekly, monthly, and annual report showing daily service water consumption and peak service water demand with time and date stamp for each meter.
 - b. For each weekly, monthly, and annual report, include sum total of submeters combined by load type, such as cooling tower makeup and irrigation showing daily service water consumption and peak service water demand.
 - c. For each weekly, monthly, and annual report, include sum total of all submeters in building showing service water consumption and peak service water demand.
- M. Energy Reports: Prepare Project-specific daily, weekly, monthly, [, **annual and since-installed**] energy reports.
 - 1. Prepare report for each purchased energy utility, indicating the following:
 - a. Time being reported with beginning and end date, and time indicated.
 - b. Consumption in units of measure commonly used to report specific utility consumption over time.
 - c. Gross area served by utility.
 - d. Consumption per unit area served using utility-specific unit of measure.
 - e. Cost per utility unit.
 - f. Utility cost per unit area.
 - g. Convert all utilities to a common energy consumption unit of measure and report for each utility.
 - h. Consumption per unit area using common unit of measure.
 - 2. Prepare report for each renewable energy source, indicating the following:
 - a. Time being reported with beginning and end date, and time indicated.
 - b. Harvested energy in units of measure commonly used to report specific harvested energy consumption over time.
 - c. Gross area served by renewable energy source.
 - d. Harvested energy per unit area served using specific unit of measure.
 - e. Cost per purchased utility unit displaced by renewable energy.
 - f. Cost savings attributed to harvested energy source.
 - g. Cost savings per unit area attributed to harvested energy.
 - h. Convert all renewable energy sources to a common energy consumption unit of measure and report for each.
 - i. Harvested energy per unit area using common unit of measure.
 - 3. Prepare purchased energy utility report for each submetered area that indicates the following:
 - a. Time being reported with beginning and end date, and time indicated.

- b. Gross area served.
 - c. Energy consumption by energy utility type.
 - d. Energy consumption per unit area by energy utility type.
 - e. Total energy consumption of all utilities in common units of measure.
 - f. Total energy consumption of all utilities in common units of measure per unit area.
 - g. Unit energy cost by energy utility type.
 - h. Energy cost by energy utility type.
 - i. Energy cost per unit area by energy utility type.
 - j. Total cost of all energy utilities.
 - k. Total cost of all energy utilities per unit area.
4. Prepare Project total purchased energy utility report that combines all purchased energy utilities and all areas served. Project total energy report is to indicate the following:
- a. Time being reported with beginning and end date, and time indicated.
 - b. Gross area served.
 - c. Energy consumption by energy utility type.
 - d. Energy consumption per unit area by energy utility type.
 - e. Total energy consumption of all utilities in common units of measure.
 - f. Total energy consumption of all utilities in common units of measure per unit area.
 - g. Unit energy cost by energy utility type.
 - h. Energy cost by energy utility type.
 - i. Energy cost per unit area by energy utility type.
 - j. Total cost of all energy utilities.
 - k. Total cost of all energy utilities per unit area.

N. HVAC System Efficiency Reports: Prepare Project-specific [**monthly**] [, **annual and since-installed**] HVAC system efficiency reports.

1. Prepare report for [**each**] chilled-water system, indicating the following:
 - a. Time being reported with beginning and end date, and time indicated.
 - b. Cooling energy supplied during period.
 - c. Power energy consumed during period by cooling equipment used to produce cooling energy supplied. [**List power consumed for each individual piece of equipment in system and summed total of all equipment in system.**]
 - d. Energy efficiency coefficient of performance determined by dividing power energy consumed into cooling energy supplied.
 - e. Energy efficiency determined by dividing cooling energy supplied into power energy consumed.
 - f. Units of measure used in report to be consistent with units indicated for system.
2. Prepare report for [**each**] heating hot-water system, indicating the following:
 - a. Time being reported with beginning and end date, and time indicated.
 - b. Heating energy supplied during period.
 - c. Fuel consumed during period by boilers used to produce heating energy supplied. [**List fuel consumed for each individual piece of equipment in system and summed total of all equipment in system.**]

- d. Energy efficiency determined by dividing heating energy supplied into fuel energy consumed.
 - e. Units of measure used in report are to be consistent with units indicated for system.
3. Prepare report for [**each**] steam system, indicating the following:
- a. Time being reported with beginning and end date, and time indicated.
 - b. Heating energy supplied during period.
 - c. Fuel consumed during period by boilers used to produce heating energy supplied. [**List fuel consumed for each individual piece of equipment in system and summed total of all equipment in system.**]
 - d. Energy efficiency determined by dividing heating energy supplied into fuel energy consumed.
 - e. Units of measure used in report are to be consistent with units indicated for system.
- O. Weather Reports:
1. Include daily report showing the following:
- a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each day calculated from a base temperature of **[55 deg F (13 deg C)]**.
 - e. Number of cooling degree-days for each day calculated from a base temperature of **[65 deg F (18 deg C)]**.
 - f. Daily minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
2. Include weekly report showing the following:
- a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each day calculated from a base temperature of **[55 deg F (13 deg C)]**.
 - e. Number of cooling degree-days for each day calculated from a base temperature of **[65 deg F (18 deg C)]**.
 - f. Weekly minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
3. Include monthly report showing the following:
- a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.

- d. Number of heating degree-days for each day calculated from a base temperature of **[55 deg F (13 deg C)]** .
 - e. Number of cooling degree-days for each day calculated from a base temperature of **[65 deg F (18 deg C)]** .
 - f. Monthly minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
4. Include annual (12-month) report showing the following:
- a. Monthly minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Monthly minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Monthly minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each month calculated from a base temperature of **[55 deg F (13 deg C)]** .
 - e. Number of cooling degree-days for each month calculated from a base temperature of **[65 deg F (18 deg C)]** .
 - f. Annual minimum, maximum, and average outdoor carbon dioxide level.
 - g. Monthly minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
- P. Standard Trends:
- 1. Trend all I/O point present values, set points, and other parameters indicated for trending.
 - 2. Associate trends into groups, and setup a trend report for each group.
 - 3. Store trends within DDC controller and uploaded to hard drives automatically on reaching **[75]** percent of DDC controller buffer limit, or by operator request, or by archiving time schedule.
 - 4. Preset trend intervals for each I/O point after review with Owner.
 - 5. Make trend intervals operator selectable from 10 seconds up to 60 minutes. Make minimum number of consecutive trend values stored at one time 100 per variable.
 - 6. When drive storage memory is full, overwrite oldest data with most recent data.
 - 7. Make archived and real-time trend data available for viewing numerically and graphically by operators.
- Q. Custom Trends: Operator-definable custom trend log for any I/O point in DDC system.
- 1. Include each trend with interval, start time, and stop time.
 - 2. Sample and store data on DDC controller, within reaching **[75]** percent storage limits of DDC controller, and then uploaded to archive on **[workstation]** **[server]** hard drives.
 - 3. Make data retrievable for use in spreadsheets and standard database programs.
- R. Programming Software:
- 1. Include programming software to execute sequences of operation indicated.
 - 2. Include programming routines in simple and easy to follow logic with detailed text comments describing what the logic does and how it corresponds to sequence of operation.
 - 3. Programming software is to be **[as follows]**:

- a. Graphic Based: Use a library of function blocks made from preprogrammed code designed for DDC control systems.
 - 1) Assemble function blocks with interconnection lines that represent to control sequence in a flowchart.
 - 2) Make programming tools viewable in real time to show present values and logical results of each function block.
 - b. Menu Based: Done by entering parameters, definitions, conditions, requirements, and constraints.
 - c. Line by Line and Text Based: Programming is to declare variable types such as local, global, real, integer, and so on, at the beginning of the program. Use descriptive comments frequently to describe programming code.
4. Include means for detecting programming errors and testing software control strategies with a simulation tool before implementing in actual control. Simulation tool may be inherent with programming software or as a separate product.

S. Database Management Software:

1. Where a separate SQL database is used for information storage, include database management software that separates database monitoring and managing functions by supporting multiple separate windows.
2. Secure database access using standard SQL authentication including ability to access data for use outside of DDC system applications.
3. Include database management function summarizing information on trend, alarm, event, and audit for the following database management actions:
 - a. Backup.
 - b. Purge.
 - c. Restore.
4. Database management software supporting the following:
 - a. Statistics: Display database server information and trend, alarm, event, and audit information on database.
 - b. Maintenance: Include method of purging records from trend, alarm, event, and audit databases by supporting separate screens for creating a backup before purging, selecting database, and allowing for retention of a selected number of day's data.
 - c. Backup: Include means to create a database backup file and select a storage location.
 - d. Restore: Include a restricted means of restoring a database by requiring operator to have proper security level.
5. Information of current database activity, including the following:
 - a. Ready.
 - b. Purging record from a database.
 - c. Action failed.
 - d. Refreshing statistics.

- e. Restoring database.
 - f. Shrinking a database.
 - g. Backing up a database.
 - h. Resetting Internet information services.
 - i. Starting network device manager.
 - j. Shutting down the network device manager.
 - k. Action successful.
- 6. Database management software monitoring functions is to continuously read database information once operator has logged on.
 - 7. Include operator notification through on-screen pop-up display and email message when database value has exceeded a warning or alarm limit.
 - 8. Monitoring settings window with the following Sections:
 - a. Allow operator to set and review scan intervals and start times.
 - b. Email: Allow operator to create and review email and phone text messages to be delivered when a warning or an alarm is generated.
 - c. Warning: Allow operator to define warning limit parameters, set reminder frequency, and link email message.
 - d. Alarm: Allow operator to define alarm limit parameters, set reminder frequency, and link email message.
 - e. Database Login: Protect system from unauthorized database manipulation by creating a read access and a write access for each of trend, alarm, event, and audit databases as well as operator proper security access to restore a database.
 - 9. Monitoring settings taskbar with following informational icons:
 - a. Normal: Indicates by color and size, or other easily identifiable means, that all databases are within their limits.
 - b. Warning: Indicates by color and size, or other easily identifiable means, that one or more databases have exceeded their warning limit.
 - c. Alarm: Indicates by color and size, or other easily identifiable means, that one or more databases have exceeded their alarm limit.

2.17 ANALYTICS SOFTWARE

A. Scope: Incorporate analytics software into DDC System:

- 1. Licensing, without Recurring Cost: No re-occurring cost for licensing and subscriptions.
- 2. Licensing: With or without re-occurring cost for licensing and subscriptions.
 - a. For products with re-occurring costs, provide incremental costs broken down over a [10] -year operating period that begins at Substantial Completion.
 - b. Setup service agreements direct to Owner.
- 3. Purpose: Analyze energy and operational data to identify faults and opportunities for improved performance and reduced energy use.

4. Verification: Verify that HVAC systems and associated sequence of operations are executing as specified or as described on Drawings, through the analysis of energy and operational data, identification of faults showing where control sequences are not functioning as prescribed, and identification of opportunities for improved performance in the operation of systems.

B. Use during Project Life:

1. During Construction: Use for verification of performance during startup, commissioning, and final acceptance of DDC system.
2. During Warranty Period: Use for continuous operational tuning of DDC system and verification of operation and designed to identify warranty issues preemptively, thus reducing failures and potential down time.
3. After Warranty Period: Use to diagnose ongoing operational degradation and for Owner to perform continuous monitoring-based commissioning.

C. Minimum Features and Capabilities:

1. Operating Systems: Current version of Windows-based operating systems.
2. Time Series Database: Database technology, designed for efficient storage and analysis of large volumes of time series data, using tagging to model and describe data; supports an open-source tagging standard.
3. Data Import: Ability to accept and normalize data from a variety of sources including SQL compatible databases, CSV format files, XML format files or web services, and other EDI techniques. Once imported, software is to provide a unified data format to enable analytics algorithms to identify patterns across different data sets.
4. Open Interfaces: Open, REST-based APIs to enable integration with third-party software applications. Open APIs are to enable data to be entered/imported into database, exported from database, posting of analytic queries, and output of analytic results. APIs are to be fully documented and available as part of standard product.
5. Host: Local deployed on DDC system network.
6. Weather Data Service: Built-in worldwide weather service providing weather data including, but not limited to, the following:
 - a. Current temperature.
 - b. High temperature for the day.
 - c. Low temperature for the day.
 - d. Sunrise and sunset times.
 - e. Relative humidity.
 - f. Degree days (heating and cooling with adjustable balance point value).
 - g. Seven-day forecast.
 - h. Historical weather data extending back at least one year.
7. Email Notification: Automatic notification of detected issues via email including, but not limited to, the following:
 - a. Immediate notification of detected issues.
 - b. Daily digest or summary of detected issues.
 - c. Ability to delineate which notifications are sent to which recipients down to the level of specifying individual issues sent to individual recipients.

D. Hardware Requirements:

1. Host on a server in a virtual environment complying with Owner's security requirements.
2. Comply with standard software and hardware profiles required by Owner.

E. Analytic Rules:

1. Custom Rule Development: Develop customized rules and algorithms tailored to operational needs and characteristics of individual facilities and needs of monitoring and verification project and fault-detection requirements of Project without depending on manufacturer for rule development. Provide tools for user development and full documentation.
2. Standard Analytic Functions: Library of standard analytic functions is to use these standard analytic functions as elements to build custom analytic rules for specific needs of individual facilities.
3. Existing library of not less than 200 standard analytic rules written for applications similar to those required for this Project.

F. Reporting:

1. Standard Views of Analytic Results: Standard views to present analytic results, automatically generated when issues are found by analytic rules including, but not limited to, the following:
 - a. Rules violations across a portfolio of sites, rules violations per site, including time, date, and duration of all violations.
 - b. Ability to assign cost relationships to rule logic to provide cost per violation.
 - c. Standard filters to enable operator to easily look at rule violations by site, data, and violation type for any selected date or date range.
 - d. Automatic calculation and presentation of Key Performance Indicators (KPIs) and to define custom KPIs as needed.
2. Custom Views of Analytic Results:
 - a. Any standard system view is to be able to be saved as a custom report including its configuration criteria, e.g., time range, sites, rule violations, or other configuration options as applicable to standard system view.
 - b. Created by making queries against the database and saving the query as a saved report executed by single mouse click.
 - c. Export: Support report views export into CSV, Excel, XML, and HTML format, accomplished in a couple of mouse clicks.

G. Energy-Specific Reporting and Information Presentation Tools:

1. Greenhouse Gas Analysis: Energy/carbon dioxide relationships; easily changed and added without involvement of software manufacturer.
2. Energy Baseline: Quantify and define energy consumption and demand baselines (including weather normalization metrics) and compare actual and forecasted energy demand and consumption against those baselines.
3. Benchmarking: Multisite benchmarking to compare energy consumption and demand profiles and baselines across all buildings within Owner's portfolio.

4. Forecasting: Forecast near-future loads by using historic trends and forecasted weather data.
5. Financial Analysis: Calculate costs based on energy consumption and demand and energy costs and associate costs with any faults discovered by any analytic function and perform model- or tariff-based calculations to determine costs.
6. Tracking of Key Performance Indicators: Definition and tracking of user-defined key performance indicators/operational metrics. Examples include energy demand and consumption normalized for area and weather, peak demand, and consumption shown with minimum and maximum ranges across any user-selectable period.
7. Correlation of Energy Use with Equipment Operation: Automatically present views showing correlation between energy demand and consumption and operation of loads associated with that usage. Include the following:
 - a. All submeters and virtual meters.
 - b. Weather data as a selectable item.

H. Implementation:

1. Apply analytic rules to all HVAC systems and equipment monitored and controlled by DDC system. To extent available, use a subset of rules in existing rules library.
2. Implement rules to aid in determining proper operation of any HVAC system with a programmed sequence of operation.
3. Generate reports to aid in verification of proper operation during initial system startup and commissioning to supplement (not replace) commissioning agent reports.
4. Prepare quarterly reports summarizing faults detected and KPIs, including recommended corrective action.

I. Training:

1. Train Owner sufficiently to use software without need for external support.

2.18 MAINTENANCE MANAGEMENT SOFTWARE

A. Scope:

1. Include complete and functional software-driven maintenance management system to perform scheduling of preventive maintenance and generation of work orders, for mechanical and electrical equipment and systems, and other equipment and systems indicated.
2. Automatically generate work orders from alarm conditions, run time, and calendar time. For each work order generated, list parts, tools, and craftspeople and define task to be performed.
3. Use work orders generated to schedule a repair or preventive maintenance routine.
4. Use work orders to track completion of work, parts used, and total cost of repair.
5. Include a database inventory tracking system to automatically update inventory database to show quantity of tools, repair parts, and expendables used for a work order.
6. Print work orders and preventive maintenance schedules[**on a printer assigned solely to maintenance management function**].

B. Additional Hardware Requirements:

1. Maintenance management software is to not require additional hardware[, **except for an additional printer that is dedicated to maintenance management**].

C. Integration: Integrate maintenance management software into DDC system.

D. Software Requirements:

1. From main menu of maintenance management system, use selection of icons to penetrate to individual functions described below.
2. Work Orders:
 - a. Automatically generate work orders initiated from alarm conditions, accumulated run time, or calendar time. Work orders generated are to specify a particular task to be accomplished including labor, material, and tools needed to accomplish work.
 - b. Include at least two of the following types of work orders:
 - 1) Corrective and Emergency Maintenance: Generate for a specific job or repair for emergency, breakdown, or scheduled work.
 - 2) Preventive Maintenance: Use on a periodic basis to generate preventive maintenance work orders.
 - c. Include the following functions:
 - 1) Work Order Tracking: Perform every function related to processing work orders including creating, approving and initiating work orders, checking their status history, and closing or reworking them when appropriate.
 - 2) Work Requests: Report any problems that require corrective maintenance activity generated by dispatchers and those people designated to request work orders.
 - 3) Quick Reporting: Report work done on an open work order or a small job.
 - 4) Work Manager: Specify type of labor to be applied to a specific work order at specific times. Include capability to dispatch one or more laborers to top-priority jobs on as-needed basis and to interrupt work in progress to reassign labor to higher priority tasks.
 - d. Reports:
 - 1) Daily Maintenance Schedule by Supervisor: List a schedule of open work orders for a specified date by supervisor.
 - 2) Equipment Cost Roll-up Report: Include a roll-up of equipment costs incurred since the date the report was last run.
 - 3) Delinquent Work Order Report: List open work orders whose target completion date is earlier than the date the report is run.
 - 4) Employee Job Assignments: List labor codes that have job assignments for specified date.
 - 5) Daily Work Order Assignment: List work orders that have labor assignments for specified date.
 - 6) Estimated versus Actual Work Order Costs: List a cost summary of outstanding work orders.

- 7) Open Work Orders Report: List open work orders for locations and equipment.
3. Inventory:
- a. Include an inventory tracking system to keep track of stocked, non-stocked, and special-order items.
 - b. Link inventory tracking to database and when items are consumed, as noted on a work order issued by system, and automatically update inventory of stocked items.
 - c. Include the following functions:
 - 1) Inventory Control: Enter, display, and update information on each inventory item. Allow viewing of master inventory records that are independent of storeroom locations or item/location records. Include a screen that lists inventory transactions that move items in or out of inventory or from one storeroom location to another. Minimum information tracked is to include the following:
 - a) Vendors supply items.
 - b) Item balances, including the bin and lot level for each storeroom location.
 - c) Alternative items.
 - 2) Issues and Transfers: Issue stock directly from inventory, with or without a work order. When transfer of stock from one location to another location occurs, provide appropriate adjustments in stock balance record. Include a trace record of stock transfers from one storeroom to another.
 - 3) Item Assembly Structures: Include modeling of equipment with inventory items and building of equipment and location hierarchies.
 - 4) Metered Material Usage:
 - a) Track usage by a piece of equipment.
 - b) Record against a standing work order for a selected piece of equipment.
 - c) Include a material usage transaction for each item of material used and provide as an input to calculation for per unit material consumption report for a piece of equipment.
 - d. Reports:
 - 1) Inventory Analysis Report: List for a given storeroom location, inventory items analysis information that allows quick identification of which inventory items represent greatest monetary investment for dollar value and rate of turnover.
 - 2) Inventory Cycle Count Report: List for a specified storeroom, inventory items that are due to be cycle-counted, based on cycle-count frequency and last count date.
 - 3) Economic Order Quantity Report: For a given storeroom location, display optimum economic ordering quantity for items in selected results set.

- 4) Inventory Pick Report: A pick list, by work order for items needed to be pulled from a designated storeroom's inventory for work orders having a target start date of specified date.
- 5) Suggested Order Report: List inventory items in selected results set that are due to be recorded, for a specified storeroom location, based on the following calculation: Suggest a reorder if current balance minus reserve quantity plus on-order quantity is less than reorder point.
- 6) Reorder Point Report: List selected set of items and optimum minimum level to have in stock based on demand, lead delivery time, and a reserve safety stock.
- 7) Inventory Valuation Report: Gives an accounting of cost of current inventory, for inventory records in a designated storeroom location.
- 8) Item Order Status: Lists items on order.
- 9) List of Expired Items: Lists expired lot items in a storeroom. Report is to include item number, description, expiration date, bin number, lot number, manufacturer lot number, and quantity of expired items in that lot and bin.
- 10) Item Availability at All Locations: Lists alternative storeroom locations for selected items.
- 11) Where Used Report: List equipment on which item is recorded as being used.

4. Equipment:

- a. Include equipment and location records; establish relationships between equipment, between locations, and between equipment and locations; track maintenance costs; and enter and review meter readings.
- b. Include the following functions:
 - 1) Equipment: Store equipment numbers and corresponding information including equipment class, location, vendor, up/down status, and maintenance costs for each piece of equipment. Include building of equipment assemblies. Provide equipment assemblies hierarchical ordering for arrangement of buildings, departments, equipment, and sub-assemblies.
 - 2) Operating Locations: Facilitate creation of records for operating locations of equipment, and track equipment that is used in multiple locations. In addition, allow hierarchical organization of equipment operating in facility by means of grouping equipment locations into areas of responsibility.
 - 3) Failure Codes: Develop and display failure hierarchies to acquire an accurate history of types of failures that affect equipment and operating locations.
 - 4) Condition Monitoring: Display time-related or limit measurements recorded for a piece of equipment. Generate work orders from this screen and to take immediate action on problem conditions.
- c. Reports:
 - 1) Availability Statistic by Location: List equipment availability by location over a user-specified period.
 - 2) Equipment Failure Summary: List total number of failures by problem code for a piece of equipment for specified period.

- 3) Detailed Equipment Failure Report by Equipment: List of failure reports for the current piece of equipment for specified period.
- 4) Equipment Hierarchy Report: List of equipment.
- 5) Equipment History Graphs: Include a graphical report in histogram format that displays equipment breakdown history over a specified period.
- 6) Equipment Measurement Report: Tabular listing and description of each measurement point for a piece of equipment and history of measurements taken for that point.
- 7) Maintenance Cost by Equipment: List of transactions costs for elected equipment in the specified date range.
- 8) Failure Count by Equipment: Graphically report number of failures for each piece of equipment showing number of failures for each piece of equipment over a specified period, occurrence of each problem code within set of failures, and failures by problem code.
- 9) Failure Analysis Graphs: Graphically report number of failures for each piece of equipment over a specified period, number of occurrences of each problem code within set of failures, and failures by problem code.
- 10) Failure Code Hierarchy Report: List of failure codes in each level of failure hierarchy.
- 11) Location Failure Summary: A summary for each selected location of failures reported and any hierarchy level locations for specified period.
- 12) Failure Summary by Location: A summary of failures for selected location and their subordinate locations that are part of hierarchical system.
- 13) Detailed Failure Report by Location: List all failures for selected location and its subordinate locations that are part of hierarchical system.
- 14) Maintenance Cost by System: List of total costs reported in a given date range for locations in selected hierarchical system.
- 15) Location Hierarchy Report: Lists member locations of hierarchical system displayed in hierarchical fashion.

5. Purchasing:

- a. Include preparation and generation of purchase requisitions and purchase orders; to report receipt of both items and services, match invoices with purchase orders and receipts and define and convert foreign currencies.
- b. Include the following functions:
 - 1) Purchase Requisition: Create and process purchase requisitions for items and services.
 - 2) Purchase Orders: Create and process purchase orders for items and services from scratch or from purchase requisitions. Record receipts of items and services.
 - 3) Invoices: Include functionality to match purchase orders with invoices and receipts. It is also possible to match a service receipt to an invoice. Project for entering of an invoice for bills that do not require purchase orders or receipts.
 - 4) Currency Management: Define currencies and specify exchange rates. Include preparation of purchase requisitions and purchase orders in currency of vendor while tracking costs in systems base currency.

c. Reports:

- 1) Invoice Approval Report: Include an approval form for entered invoices.
- 2) Inventory Receipts Register: List purchase orders and inventory received for user-specified time frame.
- 3) Direct Purchase Back-Order Report: List of items ordered as a direct purchase not received by required delivery date.
- 4) Standard Purchase Order: A printing of primary purchase order with vendors shipping information, and items purchased.
- 5) Purchase Order Status Report: List of purchase orders whose status has changed during a certain period.
- 6) Standard Purchase Requisition: A printing of primary purchase requisition, including vendor name and shipping information.

6. Job Plans:

- a. Include creation of a detailed description of work to be performed by work order. Job plan is to contain operations, procedures and list of estimated material, labor, and tools required for work.

7. Labor:

- a. Store information on employees, contractors, and crafts and include the following functions:

- 1) Labor: Create, modify, and view employee records. Employee records are to contain pay rate, overtime worked, overtime refused, specials skills, and certifications.
- 2) Crafts: Create, modify, and view craftspeople records.
- 3) Labor Reporting: Report labor usage by employee or craft externally from work orders module.

- b. Reports:

- 1) Employee Attendance Analysis: List of planned attendance, actual attendance, and vacation and sick time in hours as a percentage of planned attendance for selected employees for specified period.
- 2) Labor Productivity Analysis: List of actual labor hours by labor report category showing each by percentage.
- 3) Labor Availability versus Commitments by Crafts: A graphical report that details available labor hours versus committed work order hours by craft and day.

8. Calendars:

- a. Establish calendar records indicating working time for equipment, location, craft, and labor records.

9. Resources:

- a. Include entry and retrieval of data associated with resources required to maintain facility and to include the following functions:
 - 1) Companies: Establish and update data on vendors and other companies.
 - 2) Tools: Create and maintain information on the tools used on jobs. Make information contained within this module available to job plans and work orders.
 - 3) Service Contracts: Specify information on service contracts with vendors or manufacturers.

10. Custom Applications:

- a. Include creation of customized database tables and application screens that supplement functions specified.

11. Setup:

- a. Include configuration of database, security, and setup applications.
- b. Perform the following functions:
 - 1) Reports and Other Applications: Register reports and other applications for use within system.
 - 2) Documents: Enter, track, and link information from Drawings to equipment and inventory items.
 - 3) Chart of Accounts: Add or modify accounts; set up financial periods; enter inventory accounts, company accounts, and resource recovery accounts; and define tax codes and rates.
 - 4) Signature Security: Establish each user's access rights to modules, applications, screens, and options.
 - 5) Database Configuration: Customize database, including adjusting field lengths and modifying data types.
 - 6) Application Setup: Change position of icons and menu items on the main menu screen.
 - 7) Application Launching: Allow for connecting of third-party applications to data fields and push buttons.

12. Utilities:

- a. Include utilities module that allows system administrator to customize system and to maintain database.
- b. Include the following functions:
 - 1) Interactive SQL: Include access to database for database management functions of import/export and backup.
 - 2) Edit Windows: Display a dialog box to customize an application.
 - 3) Archive Data: Remove records from database and store them for future reference.

E. Documentation:

1. Include complete documentation for system consisting of a User Manual and Systems Administrator Guide.
2. Describe how to use each application module and screen with step-by-step instructions detailing entry and retrieval of data for functions specified.
3. Include a step-by-step description of how each report is defined and retrieved.
4. Bind documentation and clearly title it indicating volume number and use.

2.19 OFFICE APPLICATION SOFTWARE

- A. Include current version of office application software at time of Substantial Completion.
- B. Office application software package to include multiple separate applications and use a common platform for all applications.
1. Database.
 2. Email.
 3. Presentation.
 4. Publishing.
 5. Spreadsheet.
 6. Word processing.

2.20 ASHRAE 135 GATEWAYS

- A. Include BACnet communication ports, whenever available as an equipment OEM standard option, for integration via a single communication cable. BACnet-controlled plant equipment includes, but is not limited to, boilers, chillers, and variable-speed drives.
- B. Include gateways to connect BACnet to legacy systems where indicated, existing non-BACnet devices, and existing non-BACnet DDC-controlled equipment.
- C. Include with each gateway an interoperability schedule showing each point or event on legacy side that BACnet "client" will read, and each parameter that BACnet network will write to. Describe this interoperability of BACnet services, or BIBBs, defined in ASHRAE 135, Annex K.
- D. Gateway Minimum Requirements:
1. Read and view all readable object properties on non-BACnet network to BACnet network, and vice versa, where applicable.
 2. Write to all writable object properties on non-BACnet network from BACnet network, and vice versa, where applicable.
 3. Include single-pass (only one protocol to BACnet without intermediary protocols) translation from non-BACnet protocol to BACnet, and vice versa.
 4. Comply with requirements of Data Sharing Read Property, Data Sharing Write Property, Device Management Dynamic Device Binding-B, and Device Management Communication Control BIBBs in accordance with ASHRAE 135.

5. Hardware, software, software licenses, and configuration tools for operator-to-gateway communications.
6. Backup programming and parameters on CD media with ability to modify, download, backup, and restore gateway configuration.

2.21 ASHRAE 135 PROTOCOL ANALYZER

- A. Analyzer and required cables and fittings for connection to ASHRAE 135 network.
- B. Include the following minimum capabilities:
 1. Capture and store to a file data traffic on all network levels.
 2. Measure bandwidth usage.
 3. Filtering options with ability to ignore select traffic.

2.22 CTA-709.1-D NETWORK HARDWARE

- A. Routers:
 1. Network routers, including routers configured as repeaters, are to comply with requirements of CTA-709.1-D and include connection between two or more CTA-709.3 TP/FT-10 channels or between two or more CTA-709.3 TP/FT-10 channels and a TP/XF-1250 channel.
 2. IP Routers:
 - a. Perform layer three routing of CTA-709.1-D packets over an IP network in accordance with CTA-852-C.
 - b. Include appropriate connection to IP network and connections to CTA-709.3 TP/FT-10 or TP/XF-1250 network.
 - c. Support the Dynamic Host Configuration Protocol for IP configuration and use of an CTA-852-C Configuration Server (for CTA-852-C configuration), but do not rely on these services for configuration.
 - d. Capable of manual configuration via a console RS-232 port.
- B. Gateways:
 1. Perform bidirectional protocol translation from one non-CTA-709.1-D protocol to CTA-709.1-D.
 2. Incorporate a network connection to TP/FT-10 network in accordance with CTA-709.3 and a connection for non-CTA-709.1-D network.

2.23 WIRELESS ROUTERS FOR OPERATOR INTERFACE

- A. Dual-Band Wireless Routers:
 1. Description: High-speed, dual-band router with integral Ethernet ports and USB port.
 2. Technology: IEEE 802.11; 2.4 and 5 GHz speed bands.
 3. Wireless Speed: Up to [300] Mbps on 2.4 GHz band and up to [2400] Mbps on 5 GHz band.

4. Compatibility: IEEE 802.11 ac wireless devices.
5. Ethernet Ports: Four, gigabit (1000 Mbps).
6. USB Port: One, USB 2.0 or 3.0.
7. Wireless Security: Wi-Fi Protected Access (WPA) and WPA2 in accordance with IEEE 802.11.

2.24 DDC CONTROLLERS

- A. DDC system consisting of a combination of network controllers, programmable application controllers, and application-specific controllers to satisfy performance requirements indicated.
- B. DDC controllers to perform monitoring, control, energy optimization, and other requirements indicated.
- C. DDC controllers are to use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.
- D. Each DDC controller is capable of full and complete operation as a completely independent unit and as a part of DDC system wide distributed network.
- E. Environment Requirements:
 1. Controller hardware suitable for anticipated ambient conditions.
 2. Controllers located in conditioned space rated for operation at [32 to 120 deg F (0 to 50 deg C)] .
 3. Controllers located outdoors rated for operation at [40 to 150 deg F (40 to 65 deg C)].
- F. Power and Noise Immunity:
 1. Operate controller at 90 to 110 percent of nominal voltage rating and perform an orderly shutdown below 80 percent of nominal voltage.
 2. Protect against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within 36 inches (900 mm) of enclosure.
- G. DDC Controller Spare Processing Capacity:
 1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:
 - a. Network Controllers: [70] percent.
 - b. Programmable Application Controllers: Not less than [70] percent.
 - c. Application-Specific Controllers: Not less than [70] percent.
 2. Memory for DDC controller's operating system and database are to include the following:
 - a. Monitoring and control.
 - b. Energy management, operation, and optimization applications.
 - c. Alarm management.
 - d. Historical trend data of all connected I/O points.
 - e. Maintenance applications.

- f. Operator interfaces.
 - g. Monitoring of manual overrides.
- H. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:
 - 1. Network Controllers:
 - a. [20] percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: [Three]
 - 2) AOs: [Three]
 - 3) BIs: [Five]
 - 4) BOs: [Three].
 - 5) Option to provide universal I/O to meet spare requirements.
 - 2. Programmable Application Controllers:
 - a. [20] percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: [Three] .
 - 2) AOs: [Three]
 - 3) BIs: [Three]
 - 4) BOs: [Three]
 - 5) Option to provide universal I/O to meet spare requirements.
 - 3. Application-Specific Controllers:
 - a. [10] percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: [Two]
 - 2) AOs: [Two] .
 - 3) BIs: [Two]
 - 4) BOs: [Two]
 - 5) Option to provide universal I/O to meet spare requirements.
- I. Maintenance and Support: Include the following features to facilitate maintenance and support:
 - 1. Mount microprocessor components on circuit cards for ease of removal and replacement.
 - 2. Means to quickly and easily disconnect controller from network.
 - 3. Means to quickly and easily access connect to field test equipment.
 - 4. Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to network.
- J. General Requirements for CTA-709.1-D DDC Controllers:
 - 1. LonMark certified.

2. Distinguishable and accessible switch, button, or pin, when pressed is to broadcast its 48-bit Node ID and Program ID over network.
3. TP/FT-10 transceiver in accordance with CTA-709.3 and connections for TP/FT-10 control network wiring.
4. TP/XF-1250 transceiver in accordance with CTA-709.3 and connections for TP/XF-1250 control network wiring.
5. Communicate using CTA-709.1-D protocol.
6. Controllers configured into subnets, as required, to comply with performance requirements indicated.
7. Network communication through LNS network management and database standard for CTA-709.1-D network devices.
8. Locally powered, not powered through network connection.
9. Functionality required to support applications indicated including, but not limited to, the following:
 - a. I/Os indicated and as required to support sequence of operation and application in which it is used. SNVTs to have meaningful names identifying the value represented by SNVT. Unless SNVT of an appropriate engineering type is unavailable, all network variables to be of SNVT with engineering units appropriate to value the variable represents.
 - b. Configurable through SCPTs defined in LonMark SCPT List, operator-defined UCPTs, network configuration inputs (NCIs) of SNVT type defined in LonMark SNVT List, NCIs of an operator-defined network variable type, or hardware settings on controller itself for all settings and parameters used by application in which it is used.
10. Programmable controllers comply with "LonMark Interoperability Guidelines" and have LonMark certification.

K. I/O Point Interface:

1. Connect hardwired I/O points to network, programmable application, and application-specific controllers.
2. Protect I/O points so shorting of point to itself, to another point, or to ground will not damage controller.
3. Protect I/O points from voltage up to 24 V of any duration so that contact will not damage controller.
4. AIs:
 - a. Include monitoring of low-voltage (0 to 10 V dc), current (4 to 20 mA) and resistance signals from thermistor and RTD sensors.
 - b. Compatible with, and field configurable to, sensor and transmitters installed.
 - c. Perform analog-to-digital (A-to-D) conversion with a minimum resolution of [8] [12] bits or better to comply with accuracy requirements indicated.
 - d. Signal conditioning including transient rejection for each AI.
 - e. Capable of being individually calibrated for zero and span.
 - f. Incorporate common-mode noise rejection of at least 50 dB from 0 to 100 Hz for differential inputs, and normal-mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10000 ohms.
 - g. External conversion resistors are not permitted.

5. AOs:
 - a. Perform analog-to-digital (A-to-D) conversion with a minimum resolution of [8] [12] bits or better to comply with accuracy requirements indicated.
 - b. Output signals range of [4 to 20 mA dc] [or] [0 to 10 V dc] as required to include proper control of output device.
 - c. Capable of being individually calibrated for zero and span.
 - d. Drift is to be not greater than 0.4 percent of range per year.
 - e. External conversion resistors are not permitted.
6. BIs:
 - a. Accept contact closures and ignore transients of less than 5 ms duration.
 - b. Isolate and protect against an applied steady-state voltage of up to 180 V ac peak.
 - c. Include a wetting current of at least 12 mA to be compatible with commonly available control devices and protected against effects of contact bounce and noise.
 - d. Sense "dry contact" closure without external power (other than that provided by controller) being applied.
 - e. Pulse accumulation input points complying with all requirements of BIs and accept up to 10 pulses per second for pulse accumulation. Include buffer to totalize pulses. Pulse accumulator is to accept rates of at least 20 pulses per second. Reset the totalized value to zero on operator's command.
7. BOs:
 - a. Include relay contact closures or triac outputs for momentary and maintained operation of output devices.
 - 1) Relay contact closures to have a minimum duration of 0.1 second and at least 180 V of isolation.
 - 2) Include electromagnetic interference suppression on all output lines to limit transients to non-damaging levels.
 - 3) Minimum contact rating to be 1 A at 24 V ac.
 - 4) Triac outputs to have at least 180 V of isolation and minimum contact rating of 1 A at 24 V ac.
 - b. Include BOs with two-state operation or a pulsed low-voltage signal for pulse-width modulation control.
 - c. BOs to be selectable for either normally open or normally closed operation.
 - d. Include tristate outputs (two coordinated BOs) for control of three-point, floating-type electronic actuators without feedback.
 - e. Limit use of three-point floating devices to VAV terminal unit control applications[, and other applications indicated on Drawings,] . Control algorithms to operate actuator to one end of its stroke once every [12] hours for verification of operator tracking.

2.25 NETWORK CONTROLLERS

A. General:

1. Include adequate number of controllers to achieve performance indicated.
2. Provide one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.
3. Include enough memory to support its operating system, database, and programming requirements with spare memory indicated.
4. Share data between networked controllers and other network devices.
5. Operating system of controller to manage I/O communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
6. Include network controllers with a real-time clock.
7. Controller to continually check status of its processor and memory circuits. If an abnormal operation is detected, controller is to assume a predetermined failure mode and generate an alarm notification.
8. Make controllers fully programmable.

B. Communication:

1. Network controllers communicate with other devices on DDC system [**Level 1**] network.
2. Network controller to also perform routing if connected to network of programmable application controllers and application-specific controllers.

C. Operator Interface:

1. Equip controllers with a service communications port for connection to [**desktop operator's workstation**] [**portable operator's workstation**] [**POT**] [**or**] [**mobile device**].
2. Local Keypad and Display:
 - a. Equip controller with local keypad and digital display for interrogating and editing data.
 - b. Use of keypad and display requires a security password.

D. Serviceability:

1. Equip controller with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Connect wiring and cable connections to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Maintain Basic Input Output System (BIOS) and programming information in event of power loss for at least [**72**] hours.

2.26 PROGRAMMABLE APPLICATION CONTROLLERS

A. General:

1. Include adequate number of controllers to achieve performance indicated.

2. Provide enough memory to support its operating system, database, and programming requirements with spare memory indicated.
3. Share data between networked controllers and other network devices.
4. Include controller with operating system to manage I/O communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
5. Include controllers [**that perform scheduling**] with a real-time clock.
6. Controller is to continually check status of its processor and memory circuits. If an abnormal operation is detected, controller assumes a predetermined failure mode and generates an alarm notification.
7. Fully programmable.

B. Communication:

1. Programmable application controllers are to communicate with other devices on network.

C. Operator Interface:

1. Equip controllers with a service communications port for connection to [**desktop operator's workstation**] [**portable operator's workstation**] [**POT**] [**or**] [**mobile device**].
2. Local Keypad and Display:
 - a. Equip controller with local keypad and digital display for interrogating and editing data.
 - b. Protect use of keypad and display by security password.

D. Serviceability:

1. Equip controller with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Connect wiring and cable connections to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Maintain BIOS and programming information in event of power loss for at least 72 hours.

2.27 APPLICATION-SPECIFIC CONTROLLERS

A. Description: Microprocessor-based controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment or system. Controllers are not fully user-programmable but are configurable and customizable for operation of equipment they are designed to control.

1. Capable of standalone operation and continued control functions without being connected to network.
2. Share data between networked controllers and other network devices.

B. Communication: Application-specific controllers are to communicate with other application-specific controllers and devices on network, and to programmable application controllers and network controllers.

- C. Operator Interface: Equip controllers with a service communications port for connection to **[desktop workstation] [portable operator's workstation] [POT] [or] [mobile device].**[Connection is to extend to port on space temperature sensor that is connected to controller.]
- D. Serviceability:
 - 1. Equip controller with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
 - 2. Connect wiring and cable connections to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
 - 3. Use nonvolatile memory and maintain all BIOS and programming information in event of power loss.

2.28 CONTROLLER SOFTWARE

- A. General:
 - 1. Software applications are to reside and operate in controllers. Edit applications through operator workstations[**or mobile devices**].
 - 2. Identify I/O points by up to **[30]** character point name and up to **[16]** -character point descriptor. Use same names throughout, including at operator workstations.
 - 3. Execute control functions within controllers using DDC algorithms.
 - 4. Configure controllers to use stored default values to ensure fail-safe operation. Use default values when there is a failure of a connected input instrument or loss of communication of a global point value.
- B. Security:
 - 1. Secure operator access using individual security passwords and user names.
 - 2. Passwords restrict operator to points, applications, and system functions as assigned by system manager.
 - 3. Record operator log-on and log-off attempts.
 - 4. Protect from unauthorized use by automatically logging off after last keystroke. Make the delay time operator-definable.
- C. Scheduling: Include capability to schedule each point or group of points in system. Each schedule is to consist of the following:
 - 1. Weekly Schedule:
 - a. Include separate schedules for each day of week.
 - b. Each schedule should include capability for start, stop, optimal start, optimal stop, and night economizer.
 - c. Each schedule may consist of up to 10 events.
 - d. When a group of objects are scheduled together, include capability to adjust start and stop times for each member.

2. Exception Schedules:

- a. Include ability for operator to designate any day of the year as an exception schedule.
- b. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by regular schedule for that day of week.

3. Holiday Schedules:

- a. Include capability for operator to define up to 99 special or holiday schedules.
- b. Place schedules on scheduling calendar with ability to repeated each year.
- c. Operator able to define length of each holiday period.

D. System Coordination:

1. Include standard application for proper coordination of equipment.
2. Include operator with a method of grouping together equipment based on function and location.
3. Include groups that may be for use in scheduling and other applications.

E. Binary Alarms:

1. Set each binary point to alarm based on operator-specified state.
2. Include capability to automatically and manually disable alarming.

F. Analog Alarms:

1. Provide each analog object with both high and low alarm limits.
2. Include capability to automatically and manually disable alarming.

G. Alarm Reporting:

1. Include ability for operators to determine action to be taken in event of an alarm.
2. Route alarms to appropriate operator workstations based on time and other conditions.
3. Include ability for alarms to start programs, print, be logged in event logs, generate custom messages, and display graphics.

H. Remote Communication:

1. Include ability for system to notify operators by phone message, text message, and email in event of an alarm.

I. Electric Power Demand Limiting:

1. Monitor building or other operator-defined electric power consumption from signals connected to electric power meter or from a watt transducer or current transformer.
2. Predict probable power demand such that action can be taken to prevent exceeding demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.

3. Accomplish demand reduction by the following means:
 - a. Reset air-handling-unit supply temperature set points.
 - b. Reset space temperature set points.
 - c. De-energize equipment based on priority.
4. Base demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables on the means by which electric power service provider computes demand charges.
5. Include demand-limiting prediction and control for any individual meter monitored by system or for total of any combination of meters.
6. Include means operator to make the following changes online:
 - a. Addition and deletion of loads controlled.
 - b. Changes in demand intervals.
 - c. Changes in demand limit for meter(s).
 - d. Maximum shutoff time for equipment.
 - e. Minimum shutoff time for equipment.
 - f. Select rotational or sequential shedding and restoring.
 - g. Shed and restore priority.
7. Include the following information and reports, to be available on an hourly, daily, weekly, monthly, and annual basis:
 - a. Total electric consumption.
 - b. Peak demand.
 - c. Date and time of peak demand.
 - d. Daily peak demand.
- J. Maintenance Management: Monitor equipment status and generate maintenance messages based on operator-designated run-time, starts, and calendar date limits.
- K. Sequencing: Include application software based on sequences of operation indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.
- L. Control Loops:
 1. Support any of the following control loops, as applicable to control required:
 - a. Two-position (on/off, open/close, slow/fast) control.
 - b. Proportional control.
 - c. Proportional plus integral (PI) control.
 - d. Proportional plus integral plus derivative (PID) control.
 - 1) Include PID algorithms with direct or reverse action and anti-windup.
 - 2) Algorithm to calculate a time-varying analog value used to position an output or stage a series of outputs.
 - 3) Make controlled variable, set point, and PID gains operator-selectable.
 - e. Adaptive (automatic tuning).

- M. Staggered Start: Prevent all controlled equipment from simultaneously restarting after a power outage. Make the order which equipment (or groups of equipment) is started, along with the time delay between starts, operator-selectable.
- N. Energy Calculations:
1. Include software to allow instantaneous power or flow rates to be accumulated and converted to energy usage data.
 2. Include algorithm that calculates a sliding-window average (rolling average). Make algorithm flexible to allow window intervals to be operator specified (such as 15, 30, or 60 minutes).
 3. Include algorithm that calculates a fixed-window average. Use a digital input signal to define start of window period (such as signal from utility meter) to synchronize fixed-window average with that used by utility.
- O. Anti-Short Cycling:
1. Protect BO points from short cycling.
 2. Feature to allow minimum on-time and off-time to be selected.
- P. On and Off Control with Differential:
1. Include algorithm that allows BO to be cycled based on a controlled variable and set point.
 2. Use direct- or reverse-acting algorithm and incorporate an adjustable differential.
- Q. Run-Time Totalization:
1. Include software to totalize run-times for all BI [**and BO**] points.
 2. Assign a high run-time alarm, if required, by operator.

2.29 ENCLOSURES

A. General:

1. House each controller and associated control accessories in [**single**] enclosure. Enclosure is to serve as central tie-in point for control devices such as switches, transmitters, transducers, power supplies, and transformers.
2. Do not house more than one controller in single enclosure.
3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.
4. Equip doors of enclosures housing controllers and components with analog or digital displays with windows to allow visual observation of displays without opening enclosure door.
5. Individual, wall-mounted, double-door enclosures maximum of [**60 inches (1500 mm)**] wide and [**36 inches (900 mm)**] high.
6. Freestanding enclosures maximum of [**48 inches (1200 mm)**] wide and [**72 inches (1800 mm)**] high.
7. Include wall-mounted enclosures with brackets suitable for mounting enclosures to wall or freestanding support stand as indicated.

8. Supply each enclosure with complete set of as-built schematics, tubing, and wiring diagrams and product literature located in pocket on inside of door. **[For enclosures with windows, include pocket on bottom of enclosure.]**

B. Internal Arrangement:

1. Arrange internal layout of enclosure to group and protect electric, and electronic components associated with controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage and low-voltage electrical and electronic products.
4. Factory or shop install products, tubing, cabling, and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks.
6. Include spare terminals, equal to not less than **[20]** percent of used terminals.
7. Include spade lugs for stranded cable and wire.
8. Install maximum of two wires on each side of terminal.
9. Include enclosure field electric power supply with toggle-type switch located at entrance inside enclosure to disconnect power.
10. Include enclosure with line-voltage nominal 20 A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with 5 A circuit breaker.
11. Mount products within enclosure on removable internal panel(s).
12. Include products mounted in enclosures with **[engraved, laminated phenolic]** nameplates (black letters on a white background). Nameplates are to have at least **1/4-inch- (6-mm-)** high lettering.
13. Route tubing cable and wire located inside enclosure within a raceway with continuous removable cover.
14. Label each end of cable, wire, and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
15. Size enclosure internal panel to include at least **[25]** percent spare area on face of panel.

C. Environmental Requirements:

1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.
2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction, and wind) on enclosure.
3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.
4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.
5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.
6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

- D. Wall-Mounted, NEMA 250, Type 4X-SS:
1. NRTL listed in accordance with UL 508A.
 2. Seams and joints are continuously welded and ground smooth.
 3. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
 4. Construct enclosure of [Type 316L] stainless steel, not less than the following:
 - a. Size Less Than 24 Inches (600 mm): 0.053 inch (1.35 mm) thick.
 - b. Size 24 Inches (600 mm) and Larger: 0.067 inch (1.7 mm) thick.
 5. Outside body and door of enclosure with brushed No. 4 finish.
 6. Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.
 - a. Sizes through 24 Inches (600 mm) Tall: Two hinges.
 - b. Sizes between 24 Inches (600 mm) through 48 Inches (1200 mm) Tall: Three hinges.
 - c. Sizes Larger Than 48 Inches (1200 mm) Tall: Four hinges.
 7. Corner-formed door, full size of enclosure face, supported using continuous piano hinge full length of door.
 8. Doors fitted with three-point (top, middle, and bottom) latch system with single, heavy-duty, liquidtight, [Type 316L] stainless steel handle with integral locking mechanism.
 9. Removable internal panel of 0.093-inch (2.36-mm) stainless steel.
 10. Internal panel mounting studs and hardware, grounding hardware, and sealing washers.
 11. Install corrosion-resistant polyester vent drain in a stainless steel sleeve at bottom of enclosure.
 12. Include enclosure with stainless steel mounting brackets.
- E. Freestanding, NEMA 250, Type 4X-SS:
1. NRTL listed in accordance with UL 508A.
 2. Seams and joints are continuously welded and ground smooth.
 3. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
 4. Construct enclosure of [Type 316L] stainless steel, not less than the following:
 - a. Size Less Than 24 Inches (600 mm): 0.053 inch (1.35 mm) thick.
 - b. Size 24 Inches (600 mm) and Larger: 0.067 inch (1.7 mm) thick.
 5. Outside enclosure and door of enclosure with brushed No. 4 finish.
 6. Doors:
 - a. Single-door enclosure sizes up to 36 inches (900 mm) wide.
 - b. Double-door enclosure sizes larger than 36 inches (900 mm) wide.
 - c. Corner-formed door(s) with continuous perimeter oil-resistant gasket, full size of enclosure face, supported using continuous piano hinge full length of door.
 - d. Doors fitted with three-point (top, middle, and bottom) latch system with single, heavy-duty, liquidtight, [Type 316L] stainless steel handle with integral locking mechanism.
 7. Removable internal panel of 0.093-inch (2.36-mm) stainless steel.

8. Internal panel mounting studs and hardware, grounding hardware, and sealing washers.
9. Install corrosion-resistant polyester vent drain in a stainless steel sleeve at bottom of enclosure.
10. Include enclosure with stainless steel mounting brackets.
11. Thermoplastic pocket on inside of door for record Drawings and Product Data.
12. Equip top of enclosure with no fewer than two lifting eyes.
13. Internal rack-mount shelves and angles, as required by application.

F. Accessories:

1. Electric Heater:

- a. Aluminum housing with brushed finish.
- b. Thermostatic control with adjustable set point from 0 to 100 deg F (minus 18 to 38 deg C).
- c. Capacity: 100, 200, 400, and 800 W, as required by application.
- d. Fan draws cool air from bottom of enclosure and passes air across thermostat and heating elements before being released into enclosure cavity. Heated air is discharged through the top of heater.

2. Ventilation Fans, Filtered Intake, and Exhaust Grilles:

- a. Number and size of fans, filters, and grilles, as required by application.
- b. Compact cooling fans engineered for 50,000 hours of continuous operation without lubrication or service.
- c. Fans capable of being installed on any surface and in any position within enclosure for spot cooling or air circulation.
- d. Thermostatic control with adjustable set point from 32 to 140 deg F (0 to 60 deg C).
- e. Airflow Capacity at Zero Pressure:
 - 1) 4-Inch (100-mm) Fan: 100 cfm (47 L/s).
 - 2) 6-Inch (150-mm) Fan: 240 cfm (113 L/s).
 - 3) 10-Inch (250-mm) Fan: 560 cfm (264 L/s).
- f. Maximum operating temperature of 158 deg F (70 deg C).
- g. 4-inch (100-mm) fan thermally protected and provided with permanently lubricated ball-bearings.
- h. 6- and 10-inch (150- and 250-mm) fans with ball-bearing construction and split capacitor motors thermally protected to avoid premature failure.
- i. Dynamically balanced impellers molded from polycarbonate material.
- j. Fan furnished with power cord and polarized plug for power connection.
- k. Fan brackets, finger guards, and mounting hardware provided with fans to complete installation.
- l. Removable Intake and Exhaust Grilles: [ABS plastic] [or] [stainless steel], of size to match fan size and suitable for NEMA 250, Types 1 and 12 enclosures.
- m. Filters for NEMA 250, Type 1 Enclosures: Washable [foam] [or] [aluminum], of size to match intake grille.
- n. Filters for NEMA 250, Type 12 Enclosures: Disposable, of size to match intake grille.

3. Air Conditioner:
 - a. Electric-powered, self-contained, air-conditioning unit specially designed for electrical enclosures to maintain temperature inside enclosure below ambient temperature outside enclosure.
 - b. Thermostatic control with adjustable set point from 60 to 120 deg F (16 to 49 deg C).
 - c. Enclosure side or top mounting with unit capacity, as required by application.
 - d. Designed for closed-loop cooling with continuous operation in ambient environments up to 125 deg F (52 deg C).
 - e. HFC refrigerant.
 - f. Reusable and washable air filter.
 - g. High-performance, industrial-grade, and high-efficiency fans.
 - h. Furnished with power cord and polarized plug for power connection.
 - i. Condensate management system with base pan side drain.
 - j. Mounting hardware, gaskets, mounting template, and instruction manual furnished with unit.
 - k. Outdoor units equipped with head pressure control for low ambient operation, compressor heater, coated condenser coil, and thermostat.
4. Thermoelectric Humidifier:
 - a. ABS plastic enclosure.
 - b. Capacity of 8 oz. (0.24 L) of water per 24 hours.
 - c. Built-in drain captures moisture and plastic hose directs moisture to outside enclosure through a drain.
 - d. Controlled to maintain enclosure relative humidity at adjustable set point.
 - e. Unit power supply is internally wired to enclosure electrical power source.
5. Framed Fixed Window Kit for NEMA 250, Types 4, 4X, and 12 Enclosures:
 - a. 0.25-inch- (6-mm-) thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
 - b. Enclosure types, except NEMA 250 Type 1, to have continuous gasket material around perimeter of window and frame to provide watertight seal.
 - c. Window kit to be factory or shop installed before shipment to Project.
6. Frameless Fixed Window Kit for NEMA 250, Type 1 Enclosures:
 - a. 0.125-inch- (3-mm-) thick, polycarbonate window mounted in enclosure door material.
 - b. Window attached to door with screw fasteners and continuous strip of high-strength, double-sided tape around window perimeter.
 - c. Window kit is factory or shop installed before shipment to Project.
7. Frame Fixed or Hinged Window Kit for NEMA 250, Types 1 and 12 Enclosures:
 - a. 0.25-inch- (6-mm-) thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
 - b. Enclosure types, except NEMA 250 Type 1, to have continuous gasket material around perimeter of window and frame to provide watertight seal.

- c. Window kit to be factory or shop installed before shipment to Project.
- 8. Bar handle with keyed cylinder lock set.

2.30 RELAYS

A. General-Purpose Relays:

- 1. NRTL listed.
- 2. Heavy-duty, electromechanical type; rated for at least [10] A at 250 V ac and 60 Hz.
- 3. SPDT, DPDT, or three-pole double-throw, as required by control application.
- 4. Plug-in-style relay with [8-pin octal] [or] [multiblade] plug for DPDT relays and [11-pin octal] [or] [multiblade] plug for three-pole double-throw relays.
- 5. Construct contacts of silver, silver alloy, or gold.
- 6. Enclose relay in a [clear transparent] polycarbonate dust-tight cover.
- 7. Include LED indication[and push-to-test button to test manual operation of relay without power on coil].
- 8. Performance:
 - a. Mechanical Life: At least [10] million cycles.
 - b. Electrical Life: At least [100,000] cycles at rated load.
 - c. Pickup Time: [15] ms or less.
 - d. Dropout Time: [10] ms or less.
 - e. Pull-in Voltage: [85] percent of rated voltage.
 - f. Dropout Voltage: [50] percent of nominal rated voltage.
 - g. Power Consumption: [2] VA or less.
 - h. Ambient Operating Temperatures: Minus 40 to 115 deg F (Minus 40 to 46 deg C).
- 9. Equip relays with coil transient suppression to limit transients to non-damaging levels.
- 10. Plug each relay into industry-standard, 35 mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
- 11. Include relay socket with screw terminals. Mold into socket the coincident screw terminal numbers.

B. Multifunction Time-Delay Relays:

- 1. NRTL listed.
- 2. Continuous-duty type, rated for at least [10] A at 240 V ac and 60 Hz.
- 3. Relay with up to [4] programmable functions to provide on/off delay, interval, and recycle timing functions.
- 4. Plug-in-style relay with either multi-pin or blade plug.
- 5. Construct contacts of silver, silver alloy, or gold.
- 6. Enclose relay in a dust-tight cover.
- 7. Include knob and dial scale for alternative digital interface for setting delay time.
- 8. Visual Status Indication: Power "On"[and Output "On"] status.
- 9. Performance:
 - a. Mechanical Life: At least [10] million cycles.
 - b. Electrical Life: At least [100,000] cycles at rated load.
 - c. Timing Ranges: Multiple ranges from [0.1] seconds to [100] minutes.
 - d. Repeatability: Within [2] percent.
 - e. Recycle Time: [45] ms.

- f. Minimum Pulse-Width Control: **[50]** ms.
 - g. Power Consumption: 5 VA or less.
 - h. Ambient Operating Temperatures: **Minus 40 to 115 deg F** (**Minus 40 to 46 deg C**).
 - 10. Equip relays with transient suppression to limit transients to non-damaging levels.
 - 11. Plug each relay into industry-standard, 35 mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
 - 12. Include relay socket with screw terminals. Mold into socket the coincident screw terminal numbers.
- C. Latching Relays:
 - 1. NRTL listed.
 - 2. Continuous-duty type, rated for at least **[10]** A at 250 V ac and 60 Hz.
 - 3. SPDT, DPDT, or three-pole double-throw, as required by control application.
 - 4. Plug-in-style relay with either multi-pin or blade plug.
 - 5. Construct contacts of silver, silver alloy, or gold.
 - 6. Enclose relay in a **[clear transparent]** polycarbonate dust-tight cover.
 - 7. Performance:
 - a. Mechanical Life: At least **[10]** million cycles.
 - b. Electrical Life: At least **[100,000]** cycles at rated load.
 - c. Pickup Time: **[15]** ms or less.
 - d. Dropout Time: **[10]** ms or less.
 - e. Pull-in Voltage: **[85]** percent of rated voltage.
 - f. Dropout Voltage: **[50]** percent of nominal rated voltage.
 - g. Power Consumption: **[2]** VA or less.
 - h. Ambient Operating Temperatures: **Minus 40 to 115 deg F** (**Minus 40 to 46 deg C**).
 - 8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
 - 9. Plug each relay into industry-standard, 35 mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
 - 10. Relay socket with screw terminals. Mold into socket the coincident screw terminal numbers.
- D. Current Sensing Relays:
 - 1. NRTL listed.
 - 2. Monitors ac current.
 - 3. Independent adjustable controls for pickup and dropout current.
 - 4. Energized when supply voltage is present and current is above pickup setting.
 - 5. De-energizes when monitored current is below dropout current.
 - 6. Dropout current is adjustable from **[50]** < to **[95]** percent of pickup current.
 - 7. Visual indication of contact status.
 - 8. Include current transformer, if required for application.
 - 9. House current sensing relay and current transformer if required in its own enclosure. Use NEMA 250, **[Type 12]** enclosure for indoors applications and NEMA 250, **[Type 4X]** for outdoor applications.
- E. Combination On-Off Status Sensor and On-Off Control Relays:
 - 1. Description:
 - a. On-off control and on-off status indication in a single device.

- b. LED status indication of activated relay and current trigger.
 - c. Closed-Open-Auto override switch located on the load side of relay.
- 2. Performance:
 - a. Ambient Temperature: **Minus 30 to 140 deg F (Minus 34 to 60 deg C).**
 - b. Voltage Rating: Single-phase loads rated for 300 V ac. Three-phase loads rated for 600 V ac.
- 3. Status Indication:
 - a. Current Sensor: Integral sensing for single-phase loads up to 20 A and external solid or split sensing ring for three-phase loads up to 150 A.
 - b. Current Sensor Range: As required by application.
 - c. Current Set Point: **[[Fixed or adjustable, as required by application].**
 - d. Current Sensor Output:
 - 1) Solid-state, SPDT contact rated for 30 V ac and dc and for 0.4 A.
 - 2) Solid-state, SPDT contact rated for 120 V ac and 1.0 A.
 - 3) Analog, 0 to 5 or 10 V dc.
 - 4) Analog, 4 to 20 mA, loop powered.
- 4. Relay: SPDT, continuous-duty coil; rated for 10-million mechanical cycles.
- 5. Enclosure: NEMA 250, **[Type 12]** enclosure for indoor applications; NEMA 250, **[Type 4X]** enclosure for outdoor applications.

2.31 ELECTRICAL POWER DEVICES

A. Control Transformers:

- 1. Sizing Criteria: Size control transformers for total connected load, plus additional **[25]** percent of connected load for future spare capacity.
- 2. Transformer Minimum Capacity: **[40]** VA.
- 3. Protection: Provide transformers with both primary and secondary fuses. **[Integral circuit breaker is acceptable in lieu of fuses.]**
- 4. Enclosure: House control transformers in NEMA 250 enclosures, type as indicated in "Performance Requirements" Article for application.

B. Power-Line Conditioners:

- 1. General Power-Line Conditioner Requirements:
 - a. Design to ensure maximum reliability, serviceability, and performance.
 - b. Overall function of power-line conditioner is to receive raw, polluted electrical power and purify it for use by electronic equipment. Power-line conditioner is to provide isolated, regulated, transient, and noise-free sinusoidal power to loads served.
- 2. Standards: NRTL listed per UL 1012.
- 3. Performance:

- a. Single phase, continuous, 100 percent duty rated kVA/kW capacity. Design to supply power for linear or nonlinear, high crest factor, resistive and reactive loads.
 - b. Automatically regulate output voltage to within [2] percent or better with input voltage fluctuations of plus 10 to minus 20 percent of nominal when system is loaded 100 percent. Use Variable Range Regulation to obtain improved line voltage regulation when operating under less than full load conditions.
 - 1) At 75 Percent Load: Output voltage automatically regulated to within [3] percent with input voltage fluctuations of plus 10 to minus 35 percent of nominal.
 - 2) At 50 Percent Load: Output voltage automatically regulated to within [3] percent with input voltage fluctuations of plus 10 to minus 40 percent of nominal.
 - 3) At 25 Percent Load: Output voltage automatically regulated to within [3] percent with input voltage fluctuations of plus 10 to minus 45 percent of nominal.
 - c. With input voltage distortion of up to 40 percent, limit the output voltage sine wave to maximum harmonic content of [5] percent.
 - d. Automatically regulate output voltage to within 2.5 percent when load (resistive) changes from zero to 100 to zero percent.
 - e. Output voltage returns to 95 percent of nominal level within two cycles and to 100 percent within three cycles when output is taken from no load to full-resistive load, or vice versa. Recovery from partial resistive load changes is corrected in a shorter period.
 - f. K Factor: [30] , designed to operate with nonlinear, non-sinusoidal, high crest factor loads without overheating.
 - g. Input power factor within 0.95 approaching unity with load power factor as poor as 0.6.
 - h. Attenuate load-generated odd current harmonics [23] dB at the input.
 - i. Electrically isolate the primary from the secondary. Meet isolation criteria as defined in NFPA 70, Article 250-5D.
 - j. Lighting and Surge Protection: Compares to UL 1449 rating of 330 V when subjected to Category B3 (6000 V/3000 A) combination waveform as established by IEEE C62.41.1 and IEEE C62.41.2.
 - k. Common-mode noise attenuation of [140] dB.
 - l. Transverse-mode noise attenuation of [120] dB.
 - m. With loss of input power for up to 16.6 ms, output sine wave remains at usable ac voltage levels.
 - n. Reliability of [200,000] hours' MTBF.
 - o. At full load, when measured at 1 m distance, audible noise is not to exceed [54] dB.
 - p. Approximately [92] percent efficient at full load.
4. Transformer Construction:
- a. Ferroresonant, dry type, convection cooled, 600 V class. Transformer windings of Class H (220 deg C) insulated copper.
 - b. Use Class H installation system throughout with operating temperatures not to exceed 150 deg C over a 40 deg C ambient temperature.

- c. Configure transformer primary for multi-input voltage. Include input terminals for source conductors and ground.
 - d. Manufacture transformer core using M-6 grade, grain-oriented, stress-relieved transformer steel.
 - e. Configure transformer secondary in 240/120 V split with 208 V tap or straight 120 V, depending on power output size.
 - f. Electrically isolate the transformer secondary windings from primary windings. Bond neutral conductor to cabinet enclosure and output neutral terminal.
 - g. Include interface terminals for output power hot, neutral, and ground conductors.
 - h. Label leads, wires, and terminals to correspond with circuit wiring diagram.
 - i. Vacuum impregnate transformer with epoxy resin.
5. Cabinet Construction:
- a. Design for panel or floor mounting.
 - b. NEMA 250, [Type 2] enclosure for indoor applications. NEMA 250, [Type 4X] for outdoor applications.
 - c. Manufacture the cabinet from heavy gauge steel complying with UL 50 or UL 508A.
 - d. Include textured baked-on paint finish.
- C. DC Power Supplies:
- 1. Description: Linear or switched, regulated power supplies with ac input to [one] [or] [multiple] dc output(s).
 - a. Include both line and load regulation to ensure stable output.
 - b. To protect both power supply and load, include power supply with an automatic current limiting circuit.
 - 2. Features:
 - a. Connection: Plug-in style suitable for mating with standard [8-pin octal] socket. Include power supply with mating mounting socket.
 - b. Housing: Enclose circuitry in a housing.
 - c. Local Adjustment: Include screw adjustment on exterior of housing for dc voltage output.
 - d. Mounting: DIN rail.
 - e. Visual status indicator.
 - 3. Performance:
 - a. Input Voltage: Nominally [120] V ac, 60 Hz.
 - b. Output Voltage: Nominally [24] V dc with plus or minus [1] <Insert value> V dc adjustment.
 - c. Output Current: Minimum [100] mA.
 - d. Load Regulation: Within [0.1] percent.
 - e. Line Regulation: Within [0.05] percent.
 - f. Stability: Within [0.1] percent of rated volts after warmup period.
 - g. Ripple: [1] mV rms.

2.32 UNINTERRUPTABLE POWER SUPPLY (UPS) UNITS

- A. Furnish local UPS units, of type indicated, installed with DDC system.
- B. DIN Rail Mounted UPS:
1. Provide continuous, regulated output power without using batteries during brown-out, surge, and spike conditions.
 2. Performance:
 - a. Capacity: Load not to exceed [75] percent of rated capacity.
 - b. Efficiency: Minimum [94] percent.
 - c. Input Voltage: Single phase, 120 V ac, compatible with field power source.
 - d. Load Power Factor Range (Crest Factor): [0.65 to 1.0] .
 - e. Output Voltage: 101 to 132 V ac, while input voltage varies between 89 and 152 V ac.
 - f. On Battery Output Voltage: Sine wave.
 - g. Inverter Overload Capacity: Minimum [150] percent for 30 seconds.
 - h. Battery Backup: [15] minutes of operation at [full] load with battery power.
 - i. Battery Recharge Time: Maximum of [four] hours to 90 percent capacity after full discharge.
 - j. Transfer Time: [6] ms.
 - k. Surge Voltage Withstand Capacity: IEEE C62.41.1 and IEEE C62.41.2, Categories A and B.
 3. Automatic bypass operation during fault or overload conditions.
 4. Integral line-interactive, power condition topology to eliminate all power contaminants.
 5. Include power switch and visual indication of power, battery, fault[, and temperature].
 6. Include audible alarm of faults with silence feature.
 7. Include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure)[and connect points to DDC system].
 8. Batteries: Sealed; maintenance free; replacement without dropping load.
- C. Tower UPS Models through 1000 VA:
1. Provide continuous, regulated output power without using batteries during brown-out, surge, and spike conditions.
 2. Performance:
 - a. Capacity: Load not to exceed [75] percent of rated capacity.
 - b. Efficiency: Complying with ENERGY STAR requirements; minimum [91] percent.
 - c. Input Voltage: Single phase, 120 V ac, compatible with field power source.
 - d. Load Power Factor Range (Crest Factor): [0.65 to 1.0] .
 - e. Output Voltage: 101 to 132 V ac, while input voltage varies between 89 and 152 V ac.
 - f. On Battery Output Voltage: Sine wave.
 - g. Inverter Overload Capacity: Minimum [150] percent for 30 seconds.
 - h. Battery Backup: [15] minutes of operation at [full] load with battery power.
 - i. Battery Recharge Time: Maximum of [four] hours to 90 percent capacity after full discharge to cutoff.
 - j. Transfer Time: [0] ms.

- k. Surge Voltage Withstand Capacity: IEEE C62.41.1 and IEEE C62.41.2, Categories A and B; 6 kV/200 and 500 A; 100 kHz ring wave.
 - 3. Automatic bypass operation during fault or overload conditions.
 - 4. Integral line-interactive, power condition topology to eliminate all power contaminants.
 - 5. Include power switch and visual indication of power, battery, fault, and temperature.
 - 6. Include audible alarm of faults and front panel silence feature.
 - 7. Receptacles: Minimum **[four]** , NEMA WD 1, NEMA WD 6 Configuration 5-15R receptacles.
 - 8. Remote Alarms: Include dry contacts (digital output points) **[or serial communication interface]** for low battery condition and battery-on (primary utility power failure) **[and connect points to DDC system]**.
 - 9. Batteries: Sealed type; maintenance free. Battery replacement is to be front accessible by user without dropping load.
 - 10. Install tower models in enclosures rated for location.
- D. Tower **[and Rack]** UPS Models through 3000 VA:
- 1. NRTL Listing: UL 1778.
 - 2. Provide continuous, regulated output power without using batteries during brown-out, surge, and spike conditions.
 - 3. Performance:
 - a. Capacity: Load not to exceed **[75]** percent of UPS rated capacity.
 - b. Efficiency: Complying with ENERGY STAR requirements; minimum **[91]** percent.
 - c. Input Voltage: Single phase, 120 V ac, plus 20 to minus 30 percent.
 - d. Power Factor: Minimum **[0.95]** at full load.
 - e. Output Voltage: Single phase, 120 V ac, within **[2]** percent.
 - f. Inverter overload capacity to be minimum **[150]** percent for 30 seconds.
 - g. Battery Backup: **[15]** minutes of operation at **[full]** load with battery power.
 - h. Battery Recharge Time: Maximum of **[6]** hours to 90 percent capacity.
 - i. Transfer Time: **[0]** ms.
 - 4. LCD display with operator interface.
 - 5. Receptacles: Minimum **[6]** , NEMA WD 1, NEMA WD 6 Configuration 5-15R or 5-20R receptacles.
 - 6. Automatic bypass operation during fault or overload conditions.
 - 7. Remote Alarms: Include dry contacts (digital output points) **[or serial communication interface]** for low battery condition and battery-on (primary utility power failure) **[and connect points to DDC system]**.
 - 8. Batteries: Sealed; maintenance free.
 - 9. Enclosures: Install tower models in enclosures rated for location. **[Install rack models installed on matching racks, as applicable to particular installation location and space availability/configuration.]**

2.33 PRESSURE INSTRUMENT SIGNAL AIR PIPING AND TUBING

- A. Products in this article are intended for use with the following:

1. Main air and signal air to pneumatically controlled instruments, actuators, and other control devices and accessories.
2. Signal air between pressure instruments, such as sensors, switches, transmitters, controllers, and accessories.

B. Copper Tubing:

1. Seamless phosphor deoxidized copper, drawn tempered[, or **soft annealed**], with chemical and physical properties in accordance with ASTM B75/B75M.
2. Performance, dimensions, weight, and tolerance in accordance with ASTM B280.
3. Diameter, as required by application, not less than nominal [**1/4 inch (6 mm)**] [**3/8 inch (10 mm)**] **<Insert size>**.
4. Wall thickness, as required by application, but not less than **0.030 inch (0.8 mm)**.
5. Copper Tubing Connectors and Fittings - Brass, Compression Type:
 - a. Single or double ferrule design creating a constant tension between fitting body and fitting nut for leak-free seal.
6. Copper Tubing Connectors and Fittings - Copper, Solder-Joint Type:
 - a. Copper Solder-Joint Fittings: Cast, ASME B16.18 or wrought, ASME B16.22.

C. Galvanized-Steel Piping (for Pneumatic/Pressure Instrument Signal Air):

1. Pipe: ASTM A53/A53M, Schedule 40.
2. Fittings: Galvanized malleable iron, ASME B16.3, Class 150.

D. Polyethylene Tubing ([**for Pneumatic**]/Pressure Instrument Signal Air):

1. Fire-resistant, black virgin polyethylene in accordance with ASTM D1248, Type 1, Class C, and Grade 5.
2. Complying with stress crack test in accordance with ASTM D1693.
3. Diameter, as required by application, of not less than nominal **1/4 inch (6 mm)**.
4. Polyethylene Tubing Connectors and Fittings - Brass, Barb Fittings:
 - a. Tapered and beaded hose barbs of push-on design; intended for low-pressure applications only.
5. Polyethylene Tubing Connectors and Fittings - Brass, Compression Type:
 - a. Specially designed for jointing polyethylene tubing to provide leak-free seal without twisting or weakening polyethylene tubing.

2.34 PROCESS TUBING

- A. Products in this article are intended for signals to instruments connected to liquid and steam systems.
- B. Copper Tubing:
1. Seamless phosphor deoxidized copper, drawn tempered with chemical and physical properties in accordance with ASTM B75/B75M.
 2. Performance, dimensions, weight, and tolerance in accordance with ASTM B280.

3. Diameter, as required by application, of not less than nominal [**3/8 inch (10 mm)**] [**1/2 inch (13 mm)**] .
4. Wall thickness, as required by application, but not less than **0.030 inch (0.8 mm)**.
5. Copper Tubing Connectors and Fittings (for Process Tubing) - Brass, Compression Type:
 - a. Single or double ferrule design creating a constant tension between fitting body and fitting nut for leak-free seal.
6. Copper Tubing Connectors and Fittings (for Process Tubing) - Brass, Solder-Joint Type:
 - a. Copper Solder-Joint Fittings: Cast, ASME B16.18 or wrought, ASME B16.22.

C. Stainless Steel Tubing (for Process Tubing):

1. Seamless Type 316 stainless steel, Grade TP, cold drawn, annealed and pickled, and free from scale.
2. Chemical and physical properties in accordance with ASTM A269/A269M.
3. Diameter, as required by application, of not less than nominal [**3/8 inch (10 mm)**] [**1/2 inch (13 mm)**] .
4. Wall thickness, as required by application, but not less than **0.035 inch (0.9 mm)**.
5. Furnish stainless steel tubing in [**20 ft. (6 m)**] straight random lengths.

D. Stainless Steel Tubing Connectors and Fittings (for Process Tubing) - Stainless Steel, Compression Type:

1. Connectors and fittings constructed from Type 316 stainless steel, with collets, flareless type.
2. Single or double ferrule design creating a constant tension between fitting body and fitting nut for leak-free seal.
3. Connect instruments to tubing with connectors having compression connector on one end and IPS or NPT thread on other end.

2.35 CONTROL WIRE AND CABLE

A. Wire: Single conductor control wiring above 24 V.

1. Wire Size: Minimum [**18**] AWG.
2. Conductors: 7/24 soft annealed copper strand with **2- to 2.5-inch (50- to 65-mm)** lay.
3. Conductor Insulation: 600 V, Type THWN or Type THHN, and 90 deg C in accordance with UL 83.
4. Conductor Insulation Colors: Black (hot), white (neutral), and green (ground).
5. Furnish on spools.

B. Single, Twisted-Shielded, Instrumentation Cable above 24 V:

1. Wire Size: Minimum [**18**] AWG.
2. Conductors: Twisted, 7/24 soft annealed copper strand with a **2- to 2.5-inch (50- to 65-mm)** lay.
3. Conductor Insulation: Type THHN/THWN or Type TFN rating.
4. Conductor Insulation Colors:
 - a. Twisted Pair: Black and white.
 - b. Twisted Triad: Black, red, and white.

5. Shielding: 100 percent type, 0.35/0.5-mil aluminum/Mylar tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
6. Outer Jacket Insulation: 600 V, 90 deg C rating, and Type TC cable.
7. Furnish on spools.

C. Single, Twisted-Shielded, Instrumentation Cable 24 V and Less:

1. Wire Size: Minimum [18] AWG.
2. Conductors: Twisted, 7/24 soft annealed copper stranding with a 2- to 2.5-inch (50- to 65-mm) lay.
3. Conductor Insulation: Nominal 15-mil thickness, constructed from flame-retardant PVC.
4. Conductor Insulation Colors:
 - a. Twisted Pair: Black and white.
 - b. Twisted Triad: Black, red, and white.
5. Shielding: 100 percent type, 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
6. Outer Jacket Insulation: 300 V, 105 deg C rating, and Type PLTC cable.
7. Furnish on spools.

D. LAN and Communication Cable: Comply with DDC system manufacturer requirements for network being installed.

1. Comply with following requirements for balanced twisted pair cable described in [Section 260523 "Control-Voltage Electrical Power Cables."] [Section 271513 "Communications Copper Horizontal Cabling."]
 - a. Plenum rated.
 - b. Unique color that is different from other cables used on Project.

2.36 RACEWAYS

- A. Comply with requirements in Section 260533 "Raceway and Boxes for Electrical Systems" for electrical power raceways and boxes.
- B. Comply with requirements in Section 270528 "Pathways for Communications Systems" for raceways for balanced twisted pair cables and optical fiber cables.

2.37 OPTICAL FIBER CABLE AND CONNECTORS

- A. Comply with requirements in Section 271323 "Communications Optical Fiber Backbone Cabling" for optical fiber backbone cabling and connectors.
- B. Comply with requirements in Section 271523 "Communications Optical Fiber Horizontal Cabling" for optical fiber horizontal cabling and connectors.

2.38 ACCESSORIES

A. Pneumatic Pressure Gauges:

1. Face Size: **1.5-inch- (38-mm-)** diameter face for pressures up through **30 psig (207 kPa)** and **2.5-inch- (65-mm-)** diameter face for greater pressures.
2. Face Markings: White dial face with black printing; **1 psig (6.9 kPa)** increment for scale ranges through **30 psig (207 kPa)** and **2 psig (13.8 kPa)** increment for larger ranges.
3. Accuracy: Within **[0.5]** percent of full-scale range.
4. Applications: Include separate gauges for branch pressure and main pressure tubing.

B. Pressure Electric Switches:

1. Description: Diaphragm-operated, snap-acting switch.
2. Performance:
 - a. Rating: Resistance loads at **[120] V ac**.
 - b. Set Point: Adjustable from **[3 to 20 psig (21 to 138 kPa)]** .
 - c. Differential: Adjustable from **[2 to 6 psig (14 to 41 kPa)]**.
3. Body and Switch Housing: Metal.

C. Control Damper Blade Limit Switches:

1. Application: Sense positive open and/or closed position of damper blades.
2. NEMA 250, **[Type 13]** , oiltight construction. Install in instrument enclosure where required for additional environmental protection.
3. Arrange for mounting application, and to prevent "over-center" operation.

D. I/P and E/P Transducers:

1. Commercial Grade:
 - a. Description: Transducer converting an electronic current (I) or voltage (E) AO signal to a proportional **[or stepped]** pneumatic signal. Unless otherwise required by operating sequence, use **3 to 15 psig (21 to 103 kPa)** pneumatic signal for pneumatic actuation.
 - b. Features:
 - 1) Auto/manual output switch, manual output control, and output pressure gauge.
 - 2) Separate zero and span calibration adjustments.
 - c. Performance:
 - 1) Accuracy: Within **[1.0]** percent of output span.
 - 2) Linearity: Within **[0.5]** percent of output span.
 - 3) Output Capacity: Not less than **[550 scim (0.54 cu. m/h)]** at **15 psig (103 kPa)**.
 - 4) Maximum Pressure: **[30 psig (206 kPa)] [40 psig (276 kPa)]** of supply pressure without damage.

- 5) Vibration: Construct entire assembly so that shock and vibration will not harm transducer or affect accuracy.
- d. Applications:
 - 1) Terminal Units: Fan-coil units, VAV units, unit heaters, and
2. Industrial Grade:
 - a. Description: Transducer converting an electronic current (I) or voltage (E) AO signal to a proportional pneumatic signal (P). Unless otherwise required by operating sequence, use 3 to 15 psig (21 to 103 kPa) pneumatic signal for pneumatic actuation. Stepped pneumatic signal is unacceptable.
 - b. Features:
 - 1) Adjustments: Separate zero and span calibration adjustments.
 - 2) Conduit Connections: Nominal 1/2 inch (13 mm).
 - 3) Enclosure: NEMA 250, [Type 4X] .
 - 4) Pressure Gauge: Integral output pressure gauge.
 - c. Performance:
 - 1) Accuracy: Within [0.5] percent of output span.
 - 2) Hysteresis: Within [0.5] percent of output span.
 - 3) Linearity: Within [0.5] percent of output span.
 - 4) Repeatability: Within [0.5] percent of output span.
 - 5) Output Capacity: Not less than [5] scfm at 15 psig (103 kPa).
 - 6) Air Consumption: Maximum of [5] scfh at 15 psig (103 kPa).
 - 7) Ambient Temperature: Suitable for operation in ambient temperature range of minus 20 to 150 deg F (minus 40 to 66 deg C).
 - 8) Pressure: Up to [50 psig (345 kPa)] without damage.
 - 9) Vibration: Construct entire assembly so shock and vibration will not harm transducer or affect accuracy.
 - d. Applications:
 - 1) All applications, except for terminal units and other applications with commercial-grade transducers.
- E. E/P Switch:
 1. Body: Cast aluminum or brass; three pipe body (common, normally open, and normally closed).
 2. Internal Components: Brass, copper, steel, or stainless steel.
 3. Connections: Barb, or threaded for mating to compression fittings.
 4. Rating: 30 psig (207 kPa) when installed in systems below 25 psig (172 kPa); 150 psig (1034 kPa) when installed in systems above 25 psig (172 kPa).
 5. Features: Include coil transient suppression.
- F. Instrument Enclosures:
 1. Application: Include instrument enclosure for secondary protection to comply with requirements indicated in "Performance Requirements" Article.

2. Certification: NRTL listed and labeled to UL 50 or UL 508A as applicable.
3. Subpanel:
 - a. Size enclosure with least 25 percent spare area on subpanel.
 - b. Mount instrument(s) within enclosure on internal subpanel(s).
4. Identification: Include on face of enclosure an engraved, laminated phenolic nameplate for each instrument installed within enclosure.
5. Raceways: For enclosures housing multiple instruments, route tubing, cable, and wiring within enclosure in a raceway having continuous removable cover.
6. Access: Provide enclosures larger than [**12 inches (300 mm)**] with hinged full-size face cover.
7. Security: Equip enclosures with lock and common key.

G. Manual Valves:

1. Brass Needle Valves:
 - a. Pressure Rating: **150 psig (1030 kPa)**.
 - b. Temperature Rating: **250 deg F (121 deg C)**.
 - c. Body: Brass.
 - d. Seat: Brass.
 - e. Handle: Aluminum, brass, or stainless steel T-bar handle.
 - f. Connections: Include tubing connections.
 - g. Applications: Copper and polyethylene pneumatic tubing.
2. Stainless Steel Needle Valves:
 - a. Pressure Rating: **5000 psig (34 474 kPa)**.
 - b. Temperature Rating: **450 deg F (232 deg C)**.
 - c. Body: Type 316 stainless steel.
 - d. Seat: Type 316 stainless steel.
 - e. Packing: [**PTFE**] <Insert material>.
 - f. Handle: Aluminum or stainless steel T-bar handle.
 - g. Connections: Include tubing connections.
 - h. Applications: Copper pneumatic tubing; copper and stainless steel process tubing.
3. Bronze Body Ball Valves:
 - a. Standard: MSS SP-110.
 - b. SWP Rating: **150 psig (1035 kPa)**.
 - c. CWP Rating: **600 psig (4140 kPa)**.
 - d. Body Design: Two piece.
 - e. Body Material: Bronze.
 - f. Ends: Threaded.
 - g. Seats: PTFE.
 - h. Stem: Stainless steel.
 - i. Ball: Stainless steel, vented.
 - j. Handle: Stainless steel with vinyl grip.
 - k. Port: Full.

H. Retractable, Wall-Mounted Cabinet for Portable Workstations:

1. Description: Surface-mounted or recessed wall cabinet for tilt-out operation of laptop computers and large-format mobile devices.

2. Cabinet Load Limit: [**50 lb (23 kg)**].
3. Cabinet Material: Carbon steel.
4. Cabinet Finish: Powder-coat epoxy; manufacturer's standard color.
5. Features include the following:
 - a. Oil-filled dampers for controlled lowering of equipment to operational position.
 - b. 3RU EIA mounting rails.
 - c. Removable laptop shelf.
 - d. Separate top compartment with mounting area, hinged rail.
 - e. Front ventilation slots.
 - f. Security key lock access.
 - g. Knockouts for conduit connections on top and bottom of cabinet.
6. Field Coordination: Provide inside center of backbox with provision to mount a field-furnished and -installed, single-gang electrical outlet box.

2.39 IDENTIFICATION

A. Instrument Air Pipe and Tubing:

1. Engraved tag bearing the following information:
 - a. Service (Example): "Instrument Air."
 - b. Pressure Range (Example): **0 to 30 psig (0 to 200 kPa)**.
2. Letter size minimum of [**0.25 inch (6 mm)**] high.
3. Engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers color-coded blue with contrasting white center exposed by engraving through outer layer.
4. Include tag with brass grommet, chain, and S-hook.

B. Control Equipment, Instruments, and Control Devices:

1. [**Self-adhesive label**] bearing unique identification.
 - a. Include instruments with unique identification identified by equipment being controlled or monitored, followed by point identification.
2. Letter size as follows:
 - a. Servers: Minimum of [**0.5 inch (13 mm)**] high.
 - b. DDC Controllers: Minimum of [**0.5 inch (13 mm)**] high.
 - c. Gateways: Minimum of [**0.5 inch (13 mm)**] high.
 - d. Repeaters: Minimum of [**0.5 inch (13 mm)**] high.
 - e. Enclosures: Minimum of [**0.5 inch (13 mm)**] high.
 - f. Electrical Power Devices: Minimum of [**0.25 inch (6 mm)**] high.
 - g. UPS units: Minimum of [**0.5 inch (13 mm)**] high.
 - h. Accessories: Minimum of [**0.25 inch (6 mm)**] high.
 - i. Instruments: Minimum of [**0.25 inch (6 mm)**] high.
 - j. Control Damper and Valve Actuators: Minimum of [**0.25 inch (6 mm)**] high.

3. Engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers color-coded black with contrasting white center exposed by engraving through outer layer.
4. Fastened with drive pins.
5. Instruments, control devices, and actuators with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require additional identification.

C. Valve Tags:

1. Brass tags and brass chains attached to valve.
2. Tag Size: Minimum [**1.5 inches (38 mm)**] in diameter.
3. Include tag with unique valve identification indicating control influence such as flow, level, pressure, or temperature; followed by location of valve, and followed by three-digit sequential number. For example: TV-1.001.
4. Valves with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.

D. Raceway and Boxes:

1. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
2. Paint cover plates on junction boxes and conduit same color as tape banding for conduits. After painting, label cover plate "HVAC Controls"[**using engraved phenolic tag**].
3. For raceways housing pneumatic tubing, add phenolic tag labeled "HVAC Instrument Air Tubing."
4. For raceways housing air signal tubing, add phenolic tag labeled "HVAC Air Signal Tubing."

E. Equipment Warning Labels:

1. Self-adhesive label with pressure-sensitive adhesive back and peel-off protective jacket.
2. Lettering size at least 14-point type with white lettering on red background.
3. Warning label to read "CAUTION-Equipment operated under remote automatic control and may start or stop at any time without warning. Switch electric power disconnecting means to OFF position before servicing."
4. Lettering to be enclosed in a white line border. Edge of label is to extend at least [**0.25 inch (6 mm)**] beyond white border.

2.40 SOURCE QUALITY CONTROL

- A. Testing Agency: [**Engage**] a qualified testing agency to evaluate the following in accordance with industry standards for each product, and to verify DDC system reliability specified in performance requirements:

1. DDC controllers.
2. Gateways.
3. Routers.

- B. Product(s) [and] [material(s)] will be considered defective if [they do] not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
 - 1. Verify compatibility with and suitability of substrates.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.
- E. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
- F. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

- A. Communication Interface to Equipment with Integral Controls:
 - 1. DDC system has communication interface with equipment having integral controls and having communication interface for remote monitoring or control.
 - 2. Equipment to Be Connected:
 - a. Domestic water booster pumps specified in Section 221123.13 "Domestic-Water Packaged Booster Pumps."
 - b. Sewage pump stations specified in Section 221343 "Facility Packaged Sewage Pumping Stations."
 - c. Sump pumps specified in Section 221429 "Sump Pumps."
 - d. Air-compressors and air driers specified in Section 221519 "General-Service Packaged Air Compressors and Receivers" and Section 226119 "Compressed-Air Equipment for Laboratory and Healthcare Facilities."
 - e. Domestic water softeners specified in Section 223100 "Domestic Water Softeners."
 - f. Domestic water heaters specified in Section 223300 "Electric, Domestic-Water Heaters" and Section 223400 "Fuel-Fired, Domestic-Water Heaters."

- g. Vacuum equipment specified in Section 226219 "Vacuum Equipment for Laboratory and Healthcare Facilities."
- h. Processed water equipment specified in Section 226719 "Processed Water Equipment for Laboratory and Healthcare Facilities."
- i. Air curtains specified in Section 233433.16 "Industrial Air Curtains."
- j. Air-terminal units specified in Section 233600 "Air Terminal Units."
- k. Kitchen hoods specified in Section 233813 "Commercial-Kitchen Hoods."
- l. Boilers specified in Section 235213 "Electric Boilers."
- m. Boilers specified in Section 235216 "Condensing Boilers."
- n. Boilers specified in Section 235223 "Cast-Iron Boilers."
- o. Boilers specified in Section 235233 "Water-Tube Boilers."
- p. Boilers specified in Section 235239 "Fire-Tube Boilers."
- q. Feedwater equipment specified in Section 235313 "Boiler Feedwater Pumps."
- r. Deaerators specified in Section 235316 "Deaerators."
- s. Chillers specified in Section 236413.13 "Direct-Fired Absorption Water Chillers."
- t. Chillers specified in Section 236413.16 "Indirect-Fired Absorption Water Chillers."
- u. Chillers specified in Section 236416 "Centrifugal Water Chillers."
- v. Chillers specified in Section 236423.13 "Air-Cooled, Scroll Water Chillers."
- w. Chillers specified in Section 236423.16 "Water-Cooled, Scroll Water Chillers."
- x. Chillers specified in Section 236426.13 "Air-Cooled, Rotary-Screw Water Chillers."
- y. Chillers specified in Section 236426.16 "Water-Cooled, Rotary-Screw Water Chillers."
- z. Cooling towers specified in Section 236513.13 "Open-Circuit, Forced-Draft Cooling Towers."
- aa. Cooling towers specified in Section 236513.16 "Closed-Circuit, Forced-Draft Cooling Towers."
- bb. Cooling towers specified in Section 236514.13 "Open-Circuit, Induced-Draft, Counterflow Cooling Towers."
- cc. Cooling towers specified in Section 236514.14 "Open-Circuit, Induced-Draft, Crossflow Cooling Towers."
- dd. Cooling towers specified in Section 236514.16 "Closed-Circuit, Induced-Draft, Counterflow Cooling Towers."
- ee. Cooling towers specified in Section 236514.17 "Closed-Circuit, Induced-Draft, Combined-Flow Cooling Towers."
- ff. Heat wheels specified in Section 237223.13 "Packaged Indoor Heat Wheel Energy Recovery Units" and Section 237223.23 "Packaged, Outdoor, Heat Wheel Energy Recovery Units."
- gg. Heat exchangers specified in Section 237223.19 "Packaged Indoor Fixed Plate Energy Recovery Units" and Section 237223.29 "Packaged, Outdoor, Fixed Plate Energy Recovery Units"
- hh. Air-handling units specified in Section 237313.13 "Indoor, Basic Air-Handling Units."
- ii. Air-handling units specified in Section 237313.16 "Indoor, Semi-Custom Air-Handling Units."
- jj. Air-handling units specified in Section 237313.19 "Indoor, Custom Air-Handling Units."
- kk. Heating and ventilating units specified in Section 237333.16 "Indoor, Indirect, Gas-Fired Heating and Ventilating Units."

- ll. Heating and ventilating units specified in Section 237339 "Indoor, Direct-Fired Heating and Ventilating Units."
- mm. Air-handling units specified in Section 237343.16 "Outdoor, Semi-Custom Air-Handling Units."
- nn. Air-handling units specified in Section 237343.19 "Outdoor, Custom Air-Handling Units."
- oo. Roof-top units specified in Section 237416.11 "Packaged, Small-Capacity, Rooftop Air-Conditioning Units."
- pp. Roof-top units specified in Section 237416.13 "Packaged, Large-Capacity, Rooftop Air-Conditioning Units."
- qq. Make-up air units specified in Section 237423.13 "Packaged, Direct-Fired, Outdoor, Heating-Only Makeup-Air Units."
- rr. Make-up air units specified in Section 237423.16 "Packaged, Indirect-Fired, Outdoor, Heating-Only Makeup-Air Units."
- ss. Dedicated outdoor-air units specified in Section 237433 "Dedicated Outdoor-Air Units."
- tt. Packaged terminal air-conditioners specified in Section 238113.11 "Packaged Terminal Air-Conditioners, Through-Wall Units."
- uu. Packaged terminal air-conditioners specified in Section 238113.12 "Packaged Terminal Air-Conditioners, Freestanding Units."
- vv. Packaged terminal air-conditioners specified in Section 238113.13 "Packaged Terminal Air-Conditioners, Outdoor, Wall-Mounted Units."
- ww. Computer-room air-conditioning units specified in Section 238123.11 "Small Capacity (6 Tons (21 kW) and Smaller), Computer-Room Air-Conditioners, Floor-Mounted Units."
- xx. Computer-room air-conditioning units specified in Section 238123.12 "Large Capacity (7 Tons (25 kW) and Larger), Computer-Room Air-Conditioners, Floor-Mounted Units."
- yy. Computer-room air-conditioning units specified in Section 238123.13 "Computer-Room Air Conditioners, Ceiling-Mounted Units."
- zz. Computer-room air-conditioning units specified in Section 238123.14 "Computer-Room Air Conditioners, Console Units."
- aaa. Computer-room, rack-mounted cooling equipment specified in Section 238123.18 "Computer-Room, Rack-Cooling Equipment."
- bbb. Variable refrigerant flow units specified in Section 238129 "Variable-Refrigerant-Flow HVAC Systems."
- ccc. Fan-coil units specified in Section 238219 "Fan Coil Units."
- ddd. Unit ventilators specified in Section 238223 "Unit Ventilators."
- eee. Wetted-element humidifiers specified in Section 238413.16 "Wetted-Element Humidifiers."
- fff. Atomizing humidifiers specified in Section 238413.19 "Atomizing Humidifiers."
- ggg. Direct-steam-injection humidifiers specified in Section 238413.23 "Direct-Steam-Injection Humidifiers."
- hhh. Self-contained steam humidifiers specified in Section 238413.29 "Self-Contained Steam Humidifiers."
- iii. Heat exchanger humidifiers specified in Section 238413.36 "Heat Exchanger Humidifiers."
- jjj. Dehumidification units specified in Section 238416.13 "Outdoor, Mechanical Dehumidification Units" and in Section 238416.16 "Indoor, Mechanical Dehumidification Units."
- kkk. Switchboards specified in Section 262300 "Low-Voltage Switchgear."

- lll. Motor-control centers specified in Section 262419 "Motor-Control Centers."
- mmm. Variable-frequency controllers specified in Section 262923 "Variable-Frequency Motor Controllers."
- nnn. Diesel emergency engine generators specified in Section 263213.13 "Diesel-Engine-Driven Generator Sets."
- ooo. Gaseous emergency engine generators specified in Section 263213.16 "Gas-Engine-Driven Generator Sets."
- ppp. Bi-fuel emergency engine generators specified in Section 263213.19 "Bi-Fuel-Engine-Driven Generator Sets."
- qqq. UPS specified in Section 263353 "Static Uninterruptible Power Supply."
- rrr. Refrigerant monitoring specified in Section 284400 "Refrigerant Detection and Alarm."

B. Communication Interface to Other Building Systems:

- 1. DDC system communicates with systems having communication interface.
- 2. Systems to Be Connected:
 - a. Elevators specified in Section 142100 "Electric Traction Elevators."
 - b. Elevators specified in Section 142113 "Electric Traction Freight Elevators."
 - c. Elevators specified in Section 142400 "Hydraulic Elevators."
 - d. Elevators specified in Section 142413 "Hydraulic Freight Elevators."
 - e. Escalators specified in Section 143100 "Escalators."
 - f. Automated water treatment systems specified in Section 232500 "HVAC Water Treatment."
 - g. Automated water treatment systems specified in Section 232516 "Water Treatment for Open-Loop Hydronic Systems."
 - h. Automated water treatment systems specified in Section 232519 "Water Treatment for Steam System Feedwater."
 - i. Power monitoring specified in Section 260913 "Electrical Power Monitoring."
 - j. Lighting controls specified in Section 260936 "Modular Dimming Controls."
 - k. Lighting controls specified in Section 260943.16 "Addressable Luminaire Lighting Controls."
 - l. Lighting controls specified in Section 260943.23 "Relay-Based Lighting Controls."
 - m. Fire-alarm system specified in Section 284621.11 "Addressable Fire-Alarm Systems."
 - n. Fire-alarm system specified in Section 284621.13 "Conventional Fire-Alarm Systems."
 - o. Access controls specified in Section 281300 "Access Control System Software and Database Management."
 - p. Intrusion detection specified in Section 283100 "Intrusion Detection."
 - q. Perimeter security specified in Section 283121 "Area and Perimeter Intrusion Detection."

3.3 PREINSTALLATION INTEGRATION TESTING

- A. Perform the following pretesting of other systems and equipment integration with DDC system before field installation:
 - 1. Test all communications in a controlled environment to ensure connectivity.

2. Load software and demonstrate functional compliance with each control sequence of operation indicated.
3. Using simulation, demonstrate compliance with sequences of operation and other requirements indicated including, but not limited to, the following:
 - a. HVAC equipment controlled through DDC system, such as boilers, chillers, pumps, and air-handling units.
 - b. Equipment faults and system recovery with fault annunciation.
 - c. Analog and Boolean value alarming and annunciation.
4. Develop a method for testing interfaces before deployment.
5. Submit documentation supporting compliance upon request.

3.4 DDC SYSTEM INTERFACE WITH EXISTING SYSTEMS

A. Interface with Existing Systems:

1. Interface DDC systems with existing systems to achieve integration indicated.
2. Monitoring and Control of DDC System by Existing Control System:
 - a. Satisfy DDC system performance requirements when monitoring and controlling DDC system by existing control system.
 - b. Operator of existing system to upload, download, monitor, trend, control, and program every I/O point in DDC system from existing control system using existing control system software and operator workstations.
 - c. Make interface so operator of existing system is not required to learn new software for remote monitoring and control from existing control system.
 - d. Make interface of DDC system into existing control system transparent to operators of existing control system and allow operators to [**program, monitor, and control**] DDC system from any operator workstation connected to existing control system.
3. Integration of Existing Control System into DDC System:
 - a. Satisfy existing control system performance requirements when monitoring and controlling existing control system through DDC system.
 - b. Operator to upload, download, monitor, alarm, report, trend, control, and program every I/O point in existing system from DDC system using operator workstations and software provided. Combined systems to share one database.
 - c. Make interface of existing control system I/O points into DDC system transparent to operators. Make all operational capabilities identical regardless of whether I/O already exists, or I/O is being installed.

B. Integration with Existing Enterprise System:

1. Interface DDC system with an existing enterprise system to adhere to Owner standards already in-place and to achieve integration.
2. Owner's control system integrator to provide the following services:

- a. Enterprise system expansion and development of graphics, logs, reports, trends, and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
 - b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
 - c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.
3. Engage Owner's control system integrator to provide the following services:
 - a. Enterprise system expansion and development of graphics, logs, reports, trends, and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
 - b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
 - c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.
 4. Attend meetings with control system integrator to integrate DDC system.

3.5 CONTROL DEVICES FOR INSTALLATION BY INSTALLERS

- A. Deliver selected control devices, specified in indicated HVAC instrumentation and control device Sections, to identified equipment and systems manufacturers for factory installation and to identified installers for field installation.
- B. Deliver the following to duct fabricator and Installer for installation in ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.
 1. Control dampers, which are specified in Section 230923.12 "Control Dampers."
 2. Airflow sensors and switches, which are specified in Section 230923.14 "Flow Instruments."
 3. Pressure sensors, which are specified in Section 230923.23 "Pressure Instruments."
- C. Deliver the following to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.
 1. Control valves, which are specified in Section 230923.11 "Control Valves."
 2. Pipe-mounted flow meters, which are specified in Section 230923.14 "Flow Instruments."
 3. Pipe-mounted sensors, switches, and transmitters. Flow meters are specified in Section 230923.14 "Flow Instruments."
 4. Tank-mounted sensors, switches, and transmitters. Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."
 5. Liquid[**and steam**] temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
 6. Pipe- and tank-mounted thermowells. Liquid[**and steam**] thermowells are specified in Section 230923.27 "Temperature Instruments."

3.6 CONTROL DEVICES FOR EQUIPMENT MANUFACTURER FACTORY INSTALLATION

- A. Deliver the following to air-handling unit manufacturer for factory installation. Include installation instructions to air-handling unit manufacturer[**and supervise installation for compliance with requirements**].
1. **[Programmable application] [or] [application-specific]** controller.
 2. Unit-mounted DDC control dampers and actuators, which are specified in Section 230923.12 "Control Dampers."
 3. Unit-mounted airflow sensors, switches, and transmitters, which are specified in Section 230923.14 "Flow Instruments."
 4. Unit-mounted gas sensors, and transmitters, which are specified in Section 230923.16 "Gas Instruments."
 5. Unit-mounted leak-detection switches, which are specified in Section 230923.18 "Leak Detection Instruments."
 6. Unit-mounted pressure sensors, switches, and transmitters, which are specified in Section 230923.23 "Pressure Instruments."
 7. Unit-mounted speed sensors, switches, and transmitters, which are specified in Section 230923.24 "Speed Instruments."
 8. Unit-mounted temperature sensors, switches, and transmitters. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
 9. Relays.
- B. Deliver the following to terminal unit manufacturer for factory installation. Include installation instructions to terminal unit manufacturer.
1. **[Programmable application] [or] [application-specific]** controller.
 2. Electric damper actuator. Damper actuators are specified in Section 230923.12 "Control Dampers."
 3. Unit-mounted flow and pressure sensors, transmitters, and transducers. Flow sensors, transmitters, and transducers are specified in Section 230923.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."
 4. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
 5. Relays.
- C. Deliver the following to fan-coil unit manufacturer for factory installation. Include installation instructions to fan-coil unit manufacturer.
1. **[Programmable application] [or] [application-specific]** controller.
 2. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
 3. Flow and pressure switches. Air and liquid flow sensors, transmitters, and transducers are specified in Section 230923.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."
 4. Leak-detection switches, which are specified in Section 230923.18 "Leak Detection Instruments."
 5. Relays.

3.7 GENERAL INSTALLATION REQUIREMENTS

- A. Install products to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Support products, tubing, piping wiring, and raceways. Brace products to prevent lateral movement and sway or a break in attachment when subjected to force.
- D. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.
- E. Fabricate openings and install sleeves in ceilings, floors, roof, and walls required by installation of products. Before proceeding with drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- F. Firestop Penetrations Made in Fire-Rated Assemblies: Comply with requirements in Section 078413 "Penetration Firestopping."
- G. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 079200 "Joint Sealants."
- H. Welding Requirements:
 - 1. Restrict welding and burning to supports and bracing.
 - 2. No equipment is cut or welded without approval. Welding or cutting will not be approved if there is risk of damage to adjacent Work.
 - 3. Welding, where approved, is to be by inert-gas electric arc process and is to be performed by qualified welders in accordance with applicable welding codes.
 - 4. If requested on-site, show satisfactory evidence of welder certificates indicating ability to perform welding work intended.
- I. Fastening Hardware:
 - 1. Wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- J. If product locations are not indicated, install products in locations that are accessible and that will permit service and maintenance from floor, equipment platforms, or catwalks without removal of permanently installed furniture and equipment.
- K. Corrosive Environments:
 - 1. Avoid or limit use of materials in corrosive airstreams and environments including, but not limited to, the following:
 - a. Laboratory exhaust-air streams.
 - b. Process exhaust-air streams.

2. When conduit is in contact with a corrosive airstream and environment, use Type 316 stainless steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment. Comply with requirements for installation of raceways and boxes specified in Section 260533 "Raceway and Boxes for Electrical Systems."
3. Where instruments are located in a corrosive airstream and are not already corrosive resistant from instrument manufacturer, field install products in NEMA 250, Type 4X instrument enclosure constructed of Type 316L stainless steel.

3.8 INSTALLATION OF WORKSTATIONS

A. Desktop Workstation Installation:

1. Install [**Owner-furnished**] workstation(s) at location(s) indicated on Drawings.
2. Install multiple-receptacle power strip with cord for use in connecting multiple workstation components to a single, duplex, electrical power receptacle.
3. Install DDC system software on workstation(s) and verify that software functions properly.
4. Develop Project-specific graphics, trends, reports, logs, and historical database.
5. Power [**each**] workstation through a [**dedicated**] UPS unit. Locate UPS adjacent to workstation.

B. Portable Workstation Installation:

1. Install DDC system software on [**Owner-furnished**] workstation(s) and verify that software functions properly.

C. Color Graphics Application:

1. Use system schematics indicated on Drawings as starting point to create graphics.
2. Develop Project-specific library of symbols for representing system equipment and products.
3. Incorporate digital images of Project-completed installation into graphics where beneficial to enhance effect.
4. Submit sketch of graphic layout with description of all text for each graphic for Owner's[**and Architect's**] review before creating graphic using graphics software.
5. Seek Owner input in graphics development once using graphics software.
6. Make final editing on-site with Owner's[**and Architect's**] review and feedback.
7. Refine graphics as necessary for Owner acceptance.
8. On receiving Owner acceptance, print a PDF file of each graphic and include with softcopy of DDC system operation and maintenance manual.

D. Retractable, Wall-Mounted Cabinet for Portable Operator's Workstation Installation:

1. Install retractable, wall-mounted portable operator's workstation cabinet(s) at following location(s) and at additional locations indicated on Drawings:
 - a. Each mechanical room.
 - b. Chiller room.
 - c. Boiler room.

2. Connect each cabinet to [**220 V, single-phase, 50 Hz**] field power source and install single gang electrical box with [**NEMA WD 6, Type 20R duplex**] receptacle and metal cover plate in cabinet. Comply with requirements in Section 262726 "Wiring Devices."
3. Connect each cabinet to Ethernet network and install an Ethernet network port for connection to portable operator workstation Ethernet cable. Comply with requirements in Section 271513 "Communications Copper Horizontal Cabling."

3.9 INSTALLATION OF POT

- A. Install [**two**] POT(s).
- B. Turn over POTs to Owner at Substantial Completion.
- C. Install software on each POT and verify that software functions properly.

3.10 INSTALLATION OF SERVERS

- A. Install number of servers required to suit requirements indicated. Review Project requirements and indicate layout of proposed server location in Shop Drawings.
- B. Install software indicated on server(s) and verify that software functions properly.
- C. Develop Project-specific graphics, trends, reports, logs, and historical database.
- D. Power servers through [**dedicated**] UPS unit. Locate UPS adjacent to server. Install rack-mounted UPS units for powering rack-mounted servers and tower UPS units for tower servers.

3.11 INSTALLATION OF PRINTERS

- A. Install [**Owner-furnished**] printers at location(s) indicated on Drawings.
- B. Install applicable printer software on [**Owner-furnished**] workstations and verify that software functions properly.

3.12 INSTALLATION OF GATEWAYS

- A. Install gateways if required for DDC system communication interface requirements indicated.
 1. Install gateway(s) required to suit indicated requirements.
- B. Test gateways to verify that communication interface functions properly.

3.13 INSTALLATION OF ROUTERS

- A. Install routers if required for DDC system communication interface requirements indicated.
 1. Install router(s) required to suit indicated requirements.

- B. Test routers to verify that communication interface functions properly.

3.14 INSTALLATION OF CONTROLLERS

- A. Install controllers in enclosures to comply with indicated requirements.
- B. Connect controllers to field power supply[**and to UPS units where indicated**].
- C. Install controllers with latest version of applicable software and configure to execute requirements indicated.
- D. Test and adjust controllers to verify operation of connected I/O to achieve performance indicated requirements while executing sequences of operation.
- E. Installation of Network Controllers:
 - 1. DDC system provider and DDC system manufacturer to determine quantity and location of network controllers to satisfy requirements indicated.[**Provide minimum quantity indicated.**]
 - 2. Install controllers in a protected location that is easily accessible by operators.
 - 3. Locate top of controller within [**84 inches (2100 mm)**] of finished floor.
- F. Installation of Programmable Application Controllers:
 - 1. DDC system provider and DDC system manufacturer to determine quantity and location of programmable application controllers to satisfy requirements indicated.[**Provide minimum quantity indicated.**]
 - 2. Install controllers in a protected location that is easily accessible by operators.
 - 3. Locate top of controller within [**84 inches (2100 mm)**] of finished floor, except where dedicated controllers are installed at terminal units.
- G. Application-Specific Controllers:
 - 1. DDC system provider and DDC system manufacturer to determine quantity and location of application-specific controllers to satisfy requirements indicated.[**Provide minimum quantity indicated.**]
 - 2. For controllers not mounted directly on equipment being controlled, install controllers in a [**protected**] location that is easily accessible by operators.

3.15 INSTALLATION OF WIRELESS ROUTERS FOR OPERATOR INTERFACE

- A. Install wireless routers to achieve optimum performance and best possible coverage.
- B. Mount wireless routers in a protected location that is within [**60 inches (1500 mm)**] of floor and easily accessible by operators.
- C. Connect wireless routers to field power supply and to UPS units if network controllers are powered through UPS units.

- D. Install wireless router with latest version of applicable software and configure wireless router with security and password protection. Create access password with not less than 12 characters consisting of letters and numbers and at least one special character. Document password in operations and maintenance manuals for reference by operators.
- E. Test and adjust wireless routers for proper operation with all types (such as, laptops, smartphones, and tablets) of wireless devices intended for use by operators.

3.16 INSTALLATION OF ENCLOSURES

- A. Install the following items in enclosures, to comply with indicated requirements:
 - 1. Gateways.
 - 2. Routers.
 - 3. Controllers.
 - 4. Electrical power devices.
 - 5. UPS units.
 - 6. Relays.
 - 7. Accessories.
 - 8. Instruments.
 - 9. Actuators.
- B. Attach wall-mounted enclosures to wall using the following types of steel struts:
 - 1. For NEMA 250, [**Type 1**] Enclosures: Use [**corrosion-resistant-coated steel**] strut and hardware.
 - 2. For NEMA 250, [**Type 4X**] < Enclosures and Enclosures Located Outdoors: Use stainless steel strut and hardware.
 - 3. Install plastic caps on exposed cut edges of strut.
- C. Align [**top**] [**or**] [**bottom**] of adjacent enclosures[**of like size**].
- D. Install floor-mounted enclosures located [**in mechanical equipment rooms**] on concrete housekeeping pads. Attach enclosure legs using [**stainless steel**] anchors.
- E. Install continuous and fully accessible wireways to connect conduit, wire, and cable to multiple adjacent enclosures. Wireways used for application are to have protection equal to NEMA 250 rating of connected enclosures.

3.17 ELECTRIC POWER CONNECTIONS

- A. Connect electrical power to DDC system products requiring electrical power connections.
- B. Design of electrical power to products not indicated with electric power is delegated to DDC system provider and installing trade to provide a fully functioning DDC system. Work is to comply with NFPA 70 and other requirements indicated.
- C. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers" for electrical power circuit breakers.

- D. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for electrical power conductors and cables.
- E. Comply with requirements in Section 260533 "Raceway and Boxes for Electrical Systems" for electrical power raceways and boxes.

3.18 INSTALLATION OF IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identification products and installation.
- B. Install [**self-adhesive labels**] with unique identification on face for each of the following:
 - 1. Server.
 - 2. Gateway.
 - 3. Router.
 - 4. Protocol analyzer.
 - 5. DDC controller.
 - 6. Enclosure.
 - 7. Electrical power device.
 - 8. UPS unit.
 - 9. Accessory.
- C. Install unique instrument identification for each instrument connected to DDC controller.
- D. Install unique identification for each control [**damper**] [**and**] [**valve**] actuator connected to DDC controller.
- E. Where product is installed above accessible tile ceiling, also install matching identification on face of ceiling grid located directly below.
- F. Where product is installed above an inaccessible ceiling, also install identification on face of access door directly below.
- G. Warning Labels and Signs:
 - 1. Permanently attach to equipment that can be automatically started by DDC control system.
 - 2. Locate where highly visible near power service entry points.

3.19 INSTALLATION OF NETWORKS

- A. Install optical fiber cable when connecting between the following network devices and when located in different buildings on campus, or when distance between devices exceeds:
 - 1. Operator workstations.
 - 2. Operator workstations and network controllers.

3. Network controllers.
- B. Install balanced twisted pair [**or optical fiber**] cable when connecting between the following network devices[**located in same building**]:
 1. Operator workstations.
 2. Operator workstations and network controllers.
 3. Network controllers.
- C. Install balanced twisted pair or copper cable (as required by equipment) when connecting between the following:
 1. Gateways.
 2. Gateways and network controllers or programmable application controllers.
 3. Routers.
 4. Routers and network controllers or programmable application controllers.
 5. Network controllers and programmable application controllers.
 6. Programmable application controllers.
 7. Programmable application controllers and application-specific controllers.
 8. Application-specific controllers.
- D. Install cable in continuous raceway.
 1. Where indicated on Drawings, cable trays may be used for copper cable in lieu of conduit.

3.20 NETWORK NAMING AND NUMBERING

- A. Coordinate with Owner and provide unique naming and addressing for networks and devices.
- B. ASHRAE 135 Networks:
 1. MAC Address:
 - a. Assign and document a MAC address unique to its network for every network device.
 - b. Ethernet Networks: Document MAC address assigned at its creation.
 - c. MS/TP Networks: Assign from 00 to 64.
 2. Network Numbering:
 - a. Assign unique numbers to each new network.
 - b. Provide ability for changing network number through device switches or operator interface.
 - c. DDC system, with all possible connected LANs, can contain up to 65,534 unique networks.
 3. Device Object Identifier Property Number:
 - a. Assign unique device object identifier property numbers or device instances for each device network.

- b. Provide for future modification of device instance number by device switches or operator interface.
 - c. LAN is to support up to 4,194,302 unique devices.
- 4. Device Object Name Property Text:
 - a. Device object name property field to support 32 minimum printable characters.
 - b. Assign unique device "Object Name" property names with plain-English descriptive names for each device.
 - 1) Example 1: Device object name for device controlling heating water boiler plant at Building 1000 would be "Heating Water System Bldg. 1000."
 - 2) Example 2: Device object name for VAV terminal unit controller could be "VAV Unit 102."
- 5. Object Name Property Text for Other Than Device Objects:
 - a. Object name property field is to support 32 minimum printable characters.
 - b. Assign object name properties with plain-English names descriptive of application.
 - 1) Example 1: "Zone 1 Temperature."
 - 2) Example 2 "Fan Start and Stop."
- 6. Object Identifier Property Number for Other Than Device Objects:
 - a. Assign object identifier property numbers according to **[Drawings]** **[or]** **[tables]** indicated.
 - b. If not indicated, object identifier property numbers may be assigned at Installer's discretion but must be approved by Owner in advance, be documented, and be unique for like object types within device.

3.21 INSTALLATION OF **[PNEUMATIC AND]**AIR SIGNAL PIPING AND TUBING

A. **[Above-Grade Pneumatic and]**Air Signal Piping and Tubing Installation:

- 1. Material Application:
 - a. Install copper tubing for sizes up through **[NTS 1 (DN 25)]** **<Insert size>** and install galvanized-steel pipe for larger sizes, except as follows:
 - 1) Tubing Exposed to View: Polyethylene tubing installed in raceways may be used in lieu of copper tubing where exposed to view.
 - 2) Concealed Tubing: Polyethylene tubing may be used in lieu of copper tubing when **[[and] [concealed in walls and connecting wall-mounted instruments with recessed connections]]**.
 - b. Pneumatic Tubing: Install copper tubing**[, unless other accessible materials are indicated,]** for pneumatic main and control signals to instruments including, but not limited to, the following:

- 1) Pneumatic actuators.
 - 2) I/P transducers.
 - 3) Sensors.
 - 4) Switches.
 - 5) Transmitters.
 - c. Install copper tubing[, **unless other accessible materials are indicated,**] for air signals to instruments including, but not limited to, the following:
 - 1) Sensors.
 - 2) Switches.
 - 3) Transmitters.
 - d. Install drawn-temper copper tubing, except within **36 inches (900 mm)** of device terminations tubing is to be annealed-tempered copper tubing.
 - e. Install compression fittings to connect copper tubing to instruments, control devices, and accessories.
 - f. Install [**barbed**] fittings to connect polyethylene tubing to instruments, control devices, and accessories.
2. Routing:
 - a. Do not expose tubing in finished spaces, such as spaces with ceilings; occupied spaces, offices, and conference rooms, unless expressly approved in writing by Architect. Tubing may be exposed in areas without ceilings.
 - b. Where tubing is installed in finished occupied spaces, install the tubing in surface metal raceway with appropriate fittings only where not feasible to conceal in wall, above ceiling, or behind architectural enclosures or covers.
 - c. Install piping and tubing plumb and parallel to and at right angles with building construction.
 - d. Install multiple runs of tubing or piping in equally spaced parallel lines.
 - e. Install piping and tubing not to interfere with access to valves, equipment, duct, and equipment access doors, or obstruct personnel access and passageways of any kind.
 - f. Coordinate with other trades before installation to prevent proposed piping and tubing from interfering with pipe, duct, terminal equipment, light fixtures, conduit, and cable tray space. If changes to Shop Drawings are necessary due to field coordination, document changes on Record Drawings.
 - g. Install vibration loops in copper tubing when connecting to instruments and actuators that vibrate.
3. Support:
 - a. Space supports in accordance with MSS SP-58, except support spacing not to exceed **60 inches (1500 mm)**.
 - b. Support copper tubing with copper hangers, clips, and tube trays.
 - c. Do not use tape for support or dielectric isolation.
 - d. Install supports at each change in direction and at each branch take-off.
 - e. Attached supports to building structure independent of work of other trades. Support from ducts, pipes, cable trays, and conduits is prohibited.

- f. Attached support from building structure with threaded rods, structural shapes, or channel strut.
 - g. Install and brace supports to carry static load plus a safety margin, which will allow tubing to be serviced.
 - h. Brace supports to prevent lateral movement.
 - i. Paint steel support members that are not galvanized or zinc coated.
 - j. Support polyethylene tubing same as copper tubing.
- 4. Do not attach piping and tubing to equipment that may be removed frequently for maintenance or that may impart vibration and expansion from temperature change.
 - 5. Protect exposed tubing in mechanical equipment rooms [**and similar utility spaces**] from mechanical damage within [**76 inches (1800 mm)**] above floor. Use aluminum channel reversed and secured over tubing to protect tubing from damage.
 - 6. Joining and Makeup:
 - a. Where joining and mating dissimilar metals where galvanic action could occur, install dielectric isolation.
 - b. Install dirt leg with an isolation valve and threaded plug at each main air, connection to panel, pneumatic pilot positioner, and PRV station.
 - c. Make threaded joints for connecting to instrument equipment with connectors with a compression tubing connector on one end and threaded connection on the other end.
 - d. Make tubing bends with tube-bending tool. Hard-bends or wrinkled or flattened bends are unacceptable.
 - e. Install tube fittings in accordance with manufacturer's written instructions.
 - f. Do not make tubing connections to a fitting before completing makeup of the connection.
 - g. Align tubing with fitting. Avoid springing tube into position; this may result in excessive stress on both tubing and fitting with possible resulting leaks.
 - h. Do not install fittings close to a bend. A length of straight tubing, not deformed by bending, is required for proper connection.
 - i. Check tubing for correct diameter and wall thickness.
 - j. Cut tube ends square and deburr. Exercise care during cutting to keep tubing round.
 - k. Thread pipe on a threading machine. Ream inner edges of pipe ends, and file and grind to remove burrs.
 - l. Wrap pipe threads with single wrap of PTFE tape.
 - m. Protect piping and tubing from entrance of foreign matter.
 - 7. Do not exceed 50 percent fill capacity where tubing is installed in conduit. Support conduit in accordance with NFPA 70 unless otherwise indicated.

B. Below-Grade [**Pneumatic and**] Air Signal Piping and Tubing Installation:

- 1. Install tubing below-grade in a continuous Schedule 80, PVC conduit.
- 2. Do not exceed 50 percent fill capacity; minimum size [**2 inches (50 mm)**]
- 3. Install top of conduit at depth of at least [**24 inches (600 mm)**] below finished grade.
- 4. Install tubing in raceways dedicated to only tubing. Do not combine electrical conductors and tubing in raceways.

C. Identify above-grade piping and tubing as follows:

1. Every **50 ft. (15 m)** of straight run.
2. At least once for each branch within **36 inches (900 mm)** of main tee.
3. At each change in direction.
4. Within **36 inches (900 mm)** of each ceiling, floor, roof, and wall penetration.
5. Where exposed to and where concealed from view, including above ceiling plenums, shafts, and chases.
6. At each valve.
7. Mark each instrument tube connection with a number-coded identification. Each unique tube is to have same unique number at instrument connection and termination at opposite end of tube.

D. Valve Installation for Pneumatic Tubing:

1. Install valves full size of piping and tubing.
2. Install at the following locations:
 - a. At each branch.
 - b. Before and after each PRV.
 - c. Before and after each air dryer.
 - d. At each control device.
3. Locate valves to be readily accessible from floor.
4. Install needle valves for isolation and throttling applications. **[Option to install ball valves in lieu of needle valves for isolation only applications.]**

3.22 INSTALLATION OF PROCESS TUBING

- A. Install process tubing for signal to instruments in liquid and steam systems. Instruments include, but are not limited to, the following:
1. Meters.
 2. Sensors.
 3. Switches.
 4. Transmitters.
- B. Support tubing in accordance with MSS SP-58, but at intervals no more than **60 inches (1500 mm)** apart.
- C. Install minimum **NPS 1/2 (DN 15)** process tubing for industrial-grade sensors, transmitters, and switches. Install bushings where required.
- D. Make smooth tubing bends with a bending tool. Flattened or wrinkled bends are unacceptable.
- E. Support tubing independent of other trades.
- F. Route tubing parallel to and at right angles to building construction.
- G. Install tubing concealed in areas with ceilings.

- H. Install dirt leg with an isolation valve and threaded plug in drain valve at each connection to a transmitter and switch.
- I. Insulate process piping and tubing connected to hot water and steam systems for personnel protection if surface temperature exceeds **120 deg F (49 deg C)**. Only insulate piping and tubing within maintenance personnel reach from floor, platform, or catwalk.
- J. Wrap pipe threads of fitting in process tubing with service temperatures below **350 deg F (177 deg C)** with single wrap of PTFE tape.
- K. Coat pipe threads of fittings on process tubing in services with temperatures exceeding **350 deg F (177 deg C)** with pipe compound before being made up to reduce possibility of galling.
- L. Do not make tubing connections to a fitting before completing makeup of connection.
- M. Check tubing for correct diameter and wall thickness. Cut the tube ends square and deburred. Exercise care during cutting to keep tubing round.
- N. Do not install fittings close to a bend. Straight length of tubing, not deformed by bending, is required for proper connection.
- O. Align tubing with fitting when installed. Avoid springing tube into position.
- P. Install tubing with extreme care to keep foreign matter out of system. Plug open tubing ends to keep out dust, dirt, and moisture.
- Q. Do not attach tubing to equipment that may be removed frequently for maintenance or may impart vibration and expansion from temperature change.
- R. Protect exposed tubing in mechanical equipment rooms from inadvertent mechanical damage within [**76 inches (1800 mm)**] above floor. Use aluminum channel reversed and secured over tubing to protect tubing from damage.
- S. Below-Grade Process Tubing Installation:
 - 1. Install tubing below-grade in a continuous Schedule 80, PVC conduit.
 - 2. Do not exceed 50 percent fill capacity; minimum size [**2 inches (50 mm)**] [.
 - 3. Install top of conduit at depth of at least [**24 inches (600 mm)**] below finished grade.
 - 4. Install tubing in raceways dedicated to only process tubing. Do not combine electrical conductors and tubing in raceways.
- T. Identify above-grade process tubing as follows:
 - 1. Every **50 ft. (15 m)** of straight run.
 - 2. At least once for each branch within **36 inches (900 mm)** of main tee.
 - 3. Near each change in direction.
 - 4. Within **36 inches (900 mm)** of each ceiling, floor, roof, and wall penetration.
 - 5. Where exposed to and where concealed from view, including above ceiling plenums, shafts, and chases.
 - 6. Near each isolation valve.

7. Mark each instrument tube connection with a number-coded identification. Each unique tube is to have same unique number at instrument connection and termination at opposite end of tube.

U. Process Tubing Isolation Valves Installation:

1. Install valves full size of piping and tubing.
2. Install isolation valves at the following locations:
 - a. Process connection.
 - b. Inlet to each instrument including, sensors, transmitters, switches, gauges, and other control devices.
3. Locate valves to be readily accessible from floor.
4. Install needle valves for isolation and throttling applications. **[Option to install ball valves in lieu of needle valves for isolation only applications.]**

3.23 INSTALLATION OF CONTROL WIRE, CABLE, AND RACEWAY

A. Comply with NECA 1.

B. Wire and Cable Installation:

1. Comply with installation requirements in Section 260523 "Control-Voltage Electrical Power Cables."
2. Comply with installation requirements in Section 271313 "Communications Copper Backbone Cabling."
3. Comply with installation requirements in Section 271513 "Communications Copper Horizontal Cabling."
4. Install cables with protective sheathing that is waterproof and capable of withstanding continuous temperatures of 90 deg C with no measurable effect on physical and electrical properties of cable.
 - a. Provide shielding to prevent interference and distortion from adjacent cables and equipment.
5. Terminate wiring in a junction box.
 - a. Clamp cable over jacket in a junction box.
 - b. Individual conductors in the stripped section of cable is to be slack between the clamping point and terminal block.
6. Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.
7. Install signal transmission components in accordance with IEEE C2, REA Form 511a, NFPA 70, and as indicated.
8. Use shielded cable to transmitters.
9. Use shielded cable to temperature sensors.
10. Perform continuity and meager testing on wire and cable after installation.

C. Conduit Installation:

1. Comply with Section 260533 "Raceway and Boxes for Electrical Systems" for control-voltage conductors.
2. Comply with Section 270528 "Pathways for Communications Systems" for balanced twisted pair cabling and optical fiber installation.

3.24 INSTALLATION OF OPTICAL FIBER CABLE SYSTEMS

- A. Comply with installation requirements in Section 271323 "Communications Optical Fiber Backbone Cabling."
- B. Comply with installation requirements in Section 271523 "Communications Optical Fiber Horizontal Cabling."

3.25 FIELD QUALITY CONTROL

- A. Testing Agency: **[Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Testing of **[Pneumatic and]**Air-Signal Tubing:
 1. Test for leaks and obstructions.
 2. Disconnect each pipe and tubing line before test is performed, and blowout dust, dirt, trash, condensate, and other foreign materials with compressed air. Use commercially pure compressed air or nitrogen as distributed in gas cylinders. Use of compressed air from oil-free compressor with air dryer is an acceptable alternative for test.
 3. After foreign matter is expelled and line is free from obstructions, plug far end of tubing run.
 4. Connect pressure source to near end of tubing run with needle valve between air supply and tubing run.
 5. Connect pressure gauge accurate to within 0.5 percent of test between shutoff needle valve and tubing run under test.
 6. For air signal tubing, apply test pressure of **[1.5]** times instrument operating pressure range. Record pressure in tubing run every 10 minutes for one hour. Allowable drop in pressure in one-hour period to not exceed **[0.1]** percent of test pressure.
 7. For pneumatic system pressures above **30 psig (207 kPa)**, apply pressure of **[1.5]** times operating pressure to tubing run. Record pressure in tubing run every 10 minutes for one hour. Allowable drop in pressure in one-hour period to not exceed **[1 psig (6.9 kPa)]**.

8. For pneumatic system pressures **30 psig (207 kPa)** and below, apply pressure of **[1.5]** times operating pressure to tubing run. Record pressure in tubing run every five minutes for one hour. Allowable drop in pressure in one-hour period to not exceed **[0.5 psig (3.5 kPa)]**.

E. Optical Fiber Cable Testing:

1. Perform preinstallation, in-progress, and final tests, supplemented by additional tests, as necessary.
2. Preinstallation Cable Verification: Verify integrity and serviceability for new cable lengths before installation. This assurance may be provided by using vendor verification documents, testing, or other methods. At a minimum, furnish evidence of verification for cable attenuation and bandwidth parameters.
3. In-Progress Testing: Perform standard tests for correct pair identification and termination during installation to ensure proper installation and cable placement. Perform tests in addition to those specified if there is any reason to question condition of material furnished and installed. Testing accomplished is to be documented by agency conducting tests. Submit test results for Project record.
4. Final Testing: Perform final test of installed system to demonstrate acceptability as installed. Perform testing according to test plan supplied by DDC system manufacturer. Correct defective Work or material and retest. At a minimum, final testing for cable system, including spare cable, to verify compliance of attenuation, length, and bandwidth parameters with performance indicated.
5. Test Equipment: Use optical fiber time-domain reflectometer for testing of length and optical connectivity.
6. Test Results: Record test results and submit copy of test results for Project record.

3.26 DDC SYSTEM I/O CHECKOUT PROCEDURES

- A. Check installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
- D. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.
- E. For pneumatic products, verify that air supply for each product is properly installed.
- F. Control Damper Checkout:
 1. Verify that control dampers are installed correctly for flow direction.
 2. Verify that proper blade alignment, either parallel or opposed, has been provided.
 3. Verify that damper frame attachment is properly secured and sealed.
 4. Verify that damper actuator and linkage attachment are secure.
 5. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
 6. Verify that damper blade travel is unobstructed.

G. Control Valve Checkout:

1. Verify that control valves are installed correctly for flow direction.
2. Verify that valve body attachment is properly secured and sealed.
3. Verify that valve actuator and linkage attachment are secure.
4. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
5. Verify that valve ball, disc, or plug travel is unobstructed.
6. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace valve if leaks persist.

H. Instrument Checkout:

1. Verify that instrument is correctly installed for location, orientation, direction, and operating clearances.
2. Verify that attachment is properly secured and sealed.
3. Verify that conduit connections are properly secured and sealed.
4. Verify that wiring is properly labeled with unique identification, correct type, and size and is securely attached to proper terminals.
5. Inspect instrument tag against approved submittal.
6. For instruments with tubing connections, verify that tubing attachment is secure and isolation valves have been provided.
7. For flow instruments, verify that recommended upstream and downstream distances have been maintained.
8. For temperature instruments, verify the following:
 - a. Sensing element type and proper material.
 - b. Length and insertion.

3.27 DDC SYSTEM I/O ADJUSTMENT, CALIBRATION, AND TESTING

- A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
- B. Provide written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
- C. For each analog instrument, make three-point test of calibration for both linearity and accuracy.
- D. Equipment and procedures used for calibration to comply with instrument manufacturer's written instructions.
- E. Provide diagnostic and test equipment for calibration and adjustment.
 1. Use field testing and diagnostic instruments and equipment with an accuracy at least twice the instrument accuracy of instrument to be calibrated. For example, test and calibrate an installed instrument with accuracy of 1 percent using field testing and diagnostic instrument with accuracy of 0.5 percent or better.
- F. Calibrate each instrument in accordance with instruction manual supplied by instrument manufacturer.

- G. If after calibration the indicated performance cannot be achieved, replace out-of-tolerance instruments.
- H. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Controls Components," in the absence of specific requirements, and to supplement requirements indicated.
- I. Analog Signals:
 - 1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
 - 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
 - 3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.
- J. Digital Signals:
 - 1. Check digital signals using a jumper wire.
 - 2. Check digital signals using an ohmmeter to test for contact making or breaking.
- K. Control Dampers:
 - 1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
 - 2. Check and document open and close cycle times for applications with cycle time less than [30] seconds.
 - 3. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
- L. Control Valves:
 - 1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
 - 2. Check and document open and close cycle times for applications with cycle time less than [30] seconds.
 - 3. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
- M. Meters: Check meters at zero, 50, and 100 percent of Project design values.
- N. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.
- O. Switches: Calibrate switches to make or break contact at set points indicated.
- P. Transmitters:
 - 1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
 - 2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.

3.28 DDC SYSTEM CONTROLLER CHECKOUT

- A. Verify power supply.
 - 1. Verify voltage, phase, and hertz.
 - 2. Verify that protection from power surges is installed and functioning.
 - 3. Verify that ground fault protection is installed.
 - 4. If applicable, verify if connected to UPS unit.
 - 5. If applicable, verify if connected to backup power source.
 - 6. If applicable, verify that power conditioning units are installed.
- B. Verify that wire and cabling are properly secured to terminals and labeled with unique identification.
- C. Verify that spare I/O capacity is provided.

3.29 DDC CONTROLLER I/O CONTROL LOOP TESTS

- A. Testing:
 - 1. Test every I/O point connected to DDC controller to verify that safety and operating control set points are as indicated and as required to operate controlled system safely and at optimum performance.
 - 2. Test every I/O point throughout its full operating range.
 - 3. Test every control loop to verify that operation is stable and accurate.
 - 4. Adjust control loop proportional, integral, and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.
 - 5. Test and adjust every control loop for proper operation according to sequence of operation.
 - 6. Test software and hardware interlocks for proper operation. Correct deficiencies.
 - 7. Operate each analog point at the following:
 - a. Upper quarter of range.
 - b. Lower quarter of range.
 - c. At midpoint of range.
 - 8. Exercise each binary point.
 - 9. For every I/O point in DDC system, read and record each value at operator workstation, at DDC controller, and at field instrument simultaneously. Value displayed at operator workstation, at DDC controller, and at field instrument must match.
 - 10. Prepare and submit report documenting results for each I/O point in DDC system and include in each I/O point a description of corrective measures and adjustments made to achieve desired results.

3.30 DDC SYSTEM VALIDATION TESTS

- A. Perform validation tests before requesting final review of system. Before beginning testing, first submit Pretest Checklist and Test Plan.

- B. After [review] [approval] of Pretest Checklist and Test Plan, execute all tests and procedures indicated in plan.
- C. After testing is complete, submit completed Pretest Checklist.
- D. Pretest Checklist: Submit the following list with items checked off once verified:
1. Detailed explanation for any items that are not completed or verified.
 2. Required mechanical installation work is successfully completed and HVAC equipment is working correctly.
 3. HVAC equipment motors operate below full-load amperage ratings.
 4. Required DDC system components, wiring, and accessories are installed.
 5. Installed DDC system architecture matches approved Drawings.
 6. Control electric power circuits operate at proper voltage and are free from faults.
 7. Required surge protection is installed.
 8. DDC system network communications function properly, including uploading and downloading programming changes.
 9. Using BACnet protocol analyzer, verify that communications are error free.
 10. Each controller's programming is backed up.
 11. Equipment, products, tubing, wiring cable, and conduits are properly labeled.
 12. All I/O points are programmed into controllers.
 13. Testing, adjusting, and balancing work affecting controls is complete.
 14. Dampers and actuators zero and span adjustments are set properly.
 15. Each control damper and actuator goes to failed position on loss of power[**and loss of signal**].
 16. Valves and actuators zero and span adjustments are set properly.
 17. Each control valve and actuator goes to failed position on loss of power[**and loss of signal**].
 18. Meter, sensor, and transmitter readings are accurate and calibrated.
 19. Control loops are tuned for smooth and stable operation.
 20. View trend data where applicable.
 21. Each controller works properly in standalone mode.
 22. Safety controls and devices function properly.
 23. Interfaces with fire-alarm system function properly.
 24. Electrical interlocks function properly.
 25. Operator workstations and other interfaces are delivered, all system and database software is installed, and graphics are created.
 26. Record Drawings are completed.
- E. Test Plan:
1. Prepare and submit validation Test Plan including test procedures for performance validation tests.
 2. Address all specified functions of DDC system and sequences of operation in Test Plan.
 3. Explain detailed actions and expected results to demonstrate compliance with requirements indicated.
 4. Explain method for simulating necessary conditions of operation used to demonstrate performance.
 5. Include Test Checklist to be used to check and initial that each test has been successfully completed.
 6. Submit Test Plan documentation [10] business days before start of tests.

F. Validation Test:

1. Verify operating performance of each I/O point in DDC system.
 - a. Verify analog I/O points at operating value.
 - b. Make adjustments to out-of-tolerance I/O points.
 - 1) Identify I/O points for future reference.
 - 2) Simulate abnormal conditions to demonstrate proper function of safety devices.
 - 3) Replace instruments and controllers that cannot maintain performance indicated after adjustments.
2. Simulate conditions to demonstrate proper sequence of control.
3. Readjust settings to design values and observe ability of DDC system to establish desired conditions.
4. 24 hours after initial validation test, do as follows:
 - a. Re-check I/O points that required corrections during initial test.
 - b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.
5. 24 Hours after second validation test, do as follows:
 - a. Re-check I/O points that required corrections during second test.
 - b. Continue validation testing until I/O point is normal on two consecutive tests.
6. Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
7. After validation testing is complete, prepare and submit report indicating results of testing. For all I/O points that required correction, indicate how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.

G. DDC System Response Time Test:

1. Simulate HLC.
 - a. Heavy load to be occurrence of [50] percent of total connected binary COV, one-half of which represents "alarm" condition, and [50] percent of total connected analog COV, one-half of which represents "alarm" condition, that are initiated simultaneously on a one-time basis.
2. Initiate 10 successive occurrences of HLC and measure response time to typical alarms and status changes.
3. Measure with timer having at least 0.1-second resolution and 0.01 percent accuracy.
4. Purpose of test is to demonstrate DDC system, as follows:
 - a. Reaction to COV and alarm conditions during HLC.
 - b. Ability to update DDC system database during HLC.

5. Passing test is contingent on the following:
 - a. Alarm reporting at printer beginning no more than [**two**] seconds after initiation (time zero) of HLC.
 - b. All alarms, both binary and analog, are reported and printed; none are lost.
 - c. Compliance with response times specified.
6. Prepare and submit report documenting HLC tested and results of test including time stamp and print out of all alarms.

H. DDC System Network Bandwidth Test:

1. Test network bandwidth usage on all DDC system networks to demonstrate bandwidth usage under DDC system normal operating conditions and under simulated HLC.
2. To pass, none of DDC system networks are to use more than 70 percent of available bandwidth under normal and HLC operation.

3.31 VERIFICATION OF DDC SYSTEM WIRELESS NETWORK

- A. DDC system Installer is to design wireless DDC system networks to comply with performance requirements indicated.
- B. Verify wireless network performance through field testing and document results in a field test report.
- C. Testing and verification of all wireless devices to include, but not be limited to, the following:
 1. Speed.
 2. Online status.
 3. Signal strength.

3.32 FINAL REVIEW

- A. Submit written request to Architect] [**Construction Manager**] when DDC system is ready for final review. State the following:
 1. DDC system has been thoroughly inspected for compliance with Contract Documents and found to be in full compliance.
 2. DDC system has been calibrated, adjusted, and tested and found to comply with requirements of operational stability, accuracy, speed, and other performance requirements indicated.
 3. DDC system monitoring and control of HVAC systems results in operation according to sequences of operation indicated.
 4. DDC system is complete and ready for final review.
- B. Upon receipt of written request for final review, [**Construction Manager**] to start review within [**reasonable period**] and upon completion issue field report(s) documenting observations and deficiencies.

- C. Take prompt action to remedy deficiencies indicated in reviewer's field report(s) and submit second written request after all deficiencies have been corrected. Repeat process until no deficiencies are reported.
- D. Compensation for Subsequent Reviews: Should more than **[two]** reviews be required, DDC system manufacturer and Installer to compensate entity/entities performing reviews for total costs (labor and expenses) associated with subsequent reviews. Estimated cost of each subsequent review to be submitted and approved by DDC system manufacturer and Installer before review.
- E. Prepare and submit closeout submittals[**and begin procedures indicated in "Extended Operation Test" Article**] when no deficiencies are reported.
- F. Part of DDC system final review shall to include demonstration to parties participating in final review.
 - 1. Provide staff familiar with DDC system installed to demonstrate operation of DDC system during final review.
 - 2. Provide testing equipment to demonstrate accuracy and other performance requirements of DDC system that is requested by reviewers during final review.
 - 3. Demonstration to include, but not be limited to, the following:
 - a. Accuracy and calibration of **[20]** I/O points randomly selected by reviewers. If review finds that some I/O points are not properly calibrated and not satisfying performance requirements indicated, additional I/O points may be selected by reviewers until total I/O points being reviewed that satisfy requirements equals quantity indicated.
 - b. HVAC equipment and system hardwired and software safeties and life-safety functions are operating according to sequence of operation. Up to **[20]** I/O points to be randomly selected by reviewers. Additional I/O points may be selected by reviewers to discover problems with operation.
 - c. Correct sequence of operation after electrical power interruption and resumption after electrical power is restored for randomly selected HVAC systems.
 - d. Operation of randomly selected dampers and valves in normal-on, normal-off, and failed positions.
 - e. Reporting of alarm conditions for randomly selected alarms, including different classes of alarms, to ensure that alarms are properly received by operators and operator workstations.
 - f. Trends, summaries, logs, and reports set up for Project.
 - g. For up to **[three]** HVAC systems randomly selected by reviewers, use graph trends to show that sequence of operation is executed in correct manner and that HVAC systems operate properly through complete sequence of operation including different modes of operations indicated. Show that control loops are stable and operating at set points and respond to changes in set point of 20 percent or more.
 - h. Software's ability to communicate with controllers, operator workstations, and uploading and downloading of control programs.
 - i. Software's ability to edit control programs offline.
 - j. Data entry to show Project-specific customizing capability including parameter changes.
 - k. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.

- l. Execution of digital and analog commands in graphic mode.
- m. Spreadsheet and curve plot software and its integration with database.
- n. Online user guide and help functions.
- o. Multitasking by showing different operations occurring simultaneously on four quadrants of split screen.
- p. System speed of response compared to requirements indicated.
- q. For Each **[Network] [and] [Programmable Application]** Controller:
 - 1) Memory: Programmed data, parameters, trend, and alarm history collected during normal operation are not to be lost during power failure.
 - 2) Operator Interface: Ability to connect directly to each type of digital controller with portable workstation and mobile device. Show that maintenance personnel interface tools perform as indicated in manufacturer's technical literature.
 - 3) Standalone Ability: Demonstrate that controllers provide stable and reliable standalone operation using default values or other method for values normally read over network.
 - 4) Electric Power: Ability to disconnect any controller safely from its power source.
 - 5) Wiring Labels: Match control drawings.
 - 6) Network Communication: Ability to locate controller's location on network and communication architecture matches Shop Drawings.
 - 7) Nameplates and Tags: Accurate and permanently attached to control panel doors, instrument, actuators, and devices.
- r. For Each Operator Workstation:
 - 1) I/O points lists agree with naming conventions.
 - 2) Graphics are complete.
 - 3) UPS unit, if applicable, operates.
- s. Communications and Interoperability: Demonstrate proper interoperability of data sharing, alarm and event management, trending, scheduling, and device and network management.[**Use ASHRAE 135 protocol analyzer to help identify devices, view network traffic, and verify interoperability.**] Requirements must be met even if only one manufacturer's equipment is installed.
 - 1) Data Presentation: On each operator workstation, demonstrate graphic display capabilities.
 - 2) Reading of Any Property: Demonstrate ability to read and display any used readable object property of any device on network.
 - 3) Set-Point and Parameter Modifications: Show ability to modify set points and tuning parameters indicated.[**Modifications are made with messages and write services initiated by operator using workstation graphics, or by completing a field in menu with instructional text.**]
 - 4) Peer-to-Peer Data Exchange: Network devices are installed and configured to perform without need for operator intervention to implement Project sequence of operation and to share global data.
 - 5) Alarm and Event Management: Alarms and events are installed and prioritized according to Owner. Demonstrate that time delays and other

- logic are set up to avoid nuisance tripping. Show that operators with sufficient privileges are permitted.
- 6) Schedule Lists: Schedules are configured for start and stop, mode change, occupant overrides, and night setback as defined in sequence of operations.
 - 7) Schedule Display and Modification: Ability to display any schedule with start and stop times for calendar year. Show that all calendar entries and schedules are modifiable from any connected operator workstation by an operator with sufficient privilege.
 - 8) Archival Storage of Data: Data archiving is handled by operator workstation and server and local trend archiving and display is accomplished.
 - 9) Modification of Trend Log Object Parameters: Operator with sufficient privilege can change logged data points, sampling rate, and trend duration.
 - 10) Device and Network Management:
 - a) Display of network device status.
 - b) Display of BACnet object information.
 - c) Silencing devices transmitting erroneous data.
 - d) Time synchronization.
 - e) Remote device re-initialization.
 - f) Backup and restore network device programming and master database(s).
 - g) Configuration management of routers.

3.33 EXTENDED OPERATION TEST

- A. Operate DDC system for operating period of [14] consecutive calendar days following Substantial Completion. Coordinate exact start date of testing with Owner.
- B. Provide operator familiar with DDC system installed to man an operator workstation [**while on-site**] during eight hours of each normal business day occurring during operating period.
- C. During operating period, DDC system to demonstrate correct operation and accuracy of monitored and controlled points as well as operation capabilities of sequences, logs, trends, reports, specialized control algorithms, diagnostics, and other software indicated.
 1. Correct defects of hardware and software when they occur.
- D. Definition of Failures and Downtime during Operating Period:
 1. Failed I/O point constituting downtime is I/O point failing to perform its intended function consistently and a point physically failed due to hardware and software.
 2. Downtime is when any I/O point in DDC system is unable to fulfill its required function.
 3. Calculate downtime as elapsed time between detected point failure as confirmed by operator, and time point is restored to service.
 4. Maximum time interval allowed between DDC system detection of failure occurrence and operator confirmation is to be 0.5 hours.
 5. Log downtime in hours to nearest 0.1 hour.
 6. Power outages do not count as downtime, but do suspend test hours unless systems are provided with UPS and served through a backup power source.
 7. Hardware or software failures caused by power outages do count as downtime.

- E. During operating period, log downtime and operational problems are encountered.
1. Identify source of problem.
 2. Provide written description of corrective action taken.
 3. Record duration of downtime.
 4. Maintain log showing the following:
 - a. Time of occurrence.
 - b. Description of each occurrence and pertinent written comments for reviewer to understand scope and extent of occurrence.
 - c. Downtime for each failed I/O point.
 - d. Running total of downtime and total time of I/O point after each problem has been restored.
 5. Make log available to Owner for review at any time.
- F. For DDC system to pass extended operation test, total downtime is limited to [1] percent of total point-hours during operating period.
1. If DDC system testing results fail to comply with minimum requirements of passing at end of operating period indicated, extend operating period one consecutive day at a time until DDC system passes requirement.
- G. Base evaluation of DDC system passing test on the following calculation:
1. Count downtime on point-hour basis where total number of DDC system point-hours is equal to total number of I/O points in DDC system multiplied by total number of hours during operating period.
 2. One point-hour of downtime is one I/O point down for one hour. For example, three I/O points down for five hours is total of 15 point-hours of downtime. Four points down for one-half hour is two point-hours of downtime.
 3. Example Calculation: Maximum allowable downtime for 30-day test for DDC system with 1000 total I/O points (combined analog and binary) and passing score of 1 percent downtime is computed by 30 days x 24 h/day x 1000 points x 1 percent equals 7200 point-hours of maximum allowable downtime.
- H. Prepare test and inspection reports.

3.34 ADJUSTING

- A. Occupancy Adjustments: When requested within [12] months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [two] visits to Project during other-than-normal occupancy hours for this purpose.

3.35 MAINTENANCE SERVICE

- A. Beginning at Substantial Completion, verify that maintenance service includes [12] months' full maintenance by DDC system manufacturer's authorized service representative. Include [monthly] preventive maintenance, repair or replacement of worn or defective components,

cleaning, calibration, and adjusting as required for proper operation. Use only manufacturer's authorized replacement parts and supplies.

3.36 SOFTWARE SERVICE AGREEMENT

- A. Technical Support: Beginning at Substantial Completion, verify that service agreement includes software support for [two] year(s).
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within [two] year(s) from date of Substantial Completion. Verify that upgrading software includes operating system and new or revised licenses for using software.
 - 1. Upgrade Notice: No fewer than [30] days to allow Owner to schedule and access system and to upgrade computer equipment if necessary.

3.37 DEMONSTRATION

- A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train Owner's maintenance personnel to adjust, operate, and maintain DDC system.
- B. Extent of Training:
 - 1. Base extent of training on scope and complexity of DDC system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
 - 2. Inform Owner of anticipated training requirements if more than minimum training requirements are indicated.
 - 3. Minimum Training Requirements:
 - a. Provide not less than [10] days of training total.
 - b. Stagger training over multiple training classes to accommodate Owner's requirements. All training to occur before end of warranty period.
 - c. Break down total days of training into not more than [three] separate training classes.
 - d. Schedule training so each training class is not less than [three] consecutive day(s).
- C. Training Schedule:
 - 1. Schedule training with Owner [20] business days before expected Substantial Completion.
 - 2. Schedule training to provide Owner with at least [10] business days of notice in advance of training.
 - 3. Training to occur within normal business hours at mutually agreed on time. Unless otherwise agreed to, training to occur Monday through Friday, except on U.S. Federal holidays, with two morning sessions and two afternoon sessions. Each morning session and afternoon session to be split in half with [15] -minute break between sessions.

Morning and afternoon sessions to be separated by [30] -minute lunch period. Training, including breaks and excluding lunch period, are not to exceed [eight] hours per day.

4. Provide staggered training schedule as requested by Owner.

D. Training Attendee List and Sign-in Sheet:

1. Request from Owner in advance of training a proposed attendee list with name, phone number, and email address.
2. Provide preprinted sign-in sheet for each training session with proposed attendees listed and no fewer than six blank spaces to add additional attendees.
3. Include preprinted sign-in sheet with training session number, date and time, instructor name, phone number, email address, and brief description of content to be covered during session. List attendees with columns for name, phone number, and email address and a column for attendee signature or initials.
4. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
5. At end of each training day, send Owner an email with attachment of scanned copy (PDF) of circulated sign-in sheet for each session. [**Indicate which attendees, if any, joined for only part of training sessions**].

E. Training Attendee Headcount:

1. Plan in advance of training for [five] attendees.
2. Make allowance for Owner to add up to [two] attendee(s) at time of training.
3. Headcount may vary depending on training content covered in session. Attendee access may be restricted to some training content for purposes of maintaining system security.

F. Training Attendee Prior Knowledge: For guidance in planning required training and instruction, assume attendees have the following:

1. [**High school and technical school**] education and degree.
2. [**Advanced**] user knowledge of computers and office applications.
3. [**Advanced**] knowledge of HVAC systems.
4. [**Advanced**] knowledge of DDC systems.
5. [**Advanced**] knowledge of DDC system and products installed.

G. Attendee Training Manuals:

1. Provide each attendee with color hard copy of all training materials and visual presentations.
2. Organize hard-copy materials in three-ring binder with table of contents and individual divider tabs marked for each logical grouping of subject matter. Organize material to provide space for attendees to take handwritten notes within training manuals.
3. In addition to hard-copy materials included in training manual, provide each binder with a sleeve or pocket that includes DVD or flash drive with PDF copy of all hard-copy materials.

H. Instructor Requirements:

1. One or multiple qualified instructors, as required, to provide training.

2. Use instructors who have provided not less than **[five]** years of instructional training on not less than **[five]** past projects with similar DDC system scope and complexity to DDC system installed.

I. Organization of Training Sessions:

1. Organize training sessions into logical groupings of technical content and to reflect different levels of operators having access to system. Plan training sessions to accommodate the following three levels of operators:
 - a. Daily operators.
 - b. Advanced operators.
 - c. System managers and administrators.
2. Plan and organize training sessions to group training content to protect DDC system security. Some attendees may be restricted to some training sessions to ensure DDC system security.

J. Training Outline:

1. Submit training outline for Owner review at least **[10]** business day before scheduling training.
2. Include in outline a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session, and synopses for each lesson planned.

K. On-Site Training:

1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power, and data connectivity for instructor and each attendee.
2. Provide training materials, projector, and other audiovisual equipment used in training.
3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. Include on-site training with regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration, and service requirements.
5. Use operator workstation that is to be used with DDC system in the training. If operator workstations are unavailable, provide temporary workstation to convey training content.

L. Off-Site Training:

1. Provide conditioned training rooms and workspace with ample tables desks or tables, chairs, power, and data connectivity for each attendee.
2. Provide capability to remotely access to Project DDC system for use in training.
3. Provide operator workstation for use by each attendee.

M. Training Content for Daily Operators:

1. Basic operation of system.
2. Understanding DDC system architecture and configuration.
3. Understanding each unique product type installed including performance and service requirements for each.

4. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm, and each unique optimization routine.
5. Operating operator workstations, printers, and other peripherals.
6. Logging on and off system.
7. Accessing graphics, reports, and alarms.
8. Adjusting and changing set points and time schedules.
9. Recognizing DDC system malfunctions.
10. Understanding content of operation and maintenance manuals including control drawings.
11. Understanding physical location and placement of DDC controllers and I/O hardware.
12. Accessing data from DDC controllers.
13. Operating portable operator workstations.
14. Review of DDC testing results to establish basic understanding of DDC system operating performance and HVAC system limitations as of Substantial Completion.
15. Running each specified report and log.
16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
18. Executing digital and analog commands in graphic mode.
19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.
20. Demonstrating DDC system performance through trend logs and command tracing.
21. Demonstrating scan, update, and alarm responsiveness.
22. Demonstrating spreadsheet and curve plot software, and its integration with database.
23. Demonstrating on-line user guide, and help function and mail facility.
24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
25. Demonstrating the following for HVAC systems and equipment controlled by DDC system:
 - a. Operation of HVAC equipment in normal-off, normal-on, and failed conditions while observing individual equipment, dampers, and valves for correct position under each condition.
 - b. For HVAC equipment with factory-installed software, show that integration into DDC system is able to communicate with DDC controllers or gateways, as applicable.
 - c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and unoccupied modes, warm-up and cool-down cycles, and other modes of operation indicated.
 - d. Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
 - e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
 - f. Each control loop responds to set-point adjustment and stabilizes within time period indicated.
 - g. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.

N. Training Content for Advanced Operators:

1. Making and changing workstation graphics.
2. Creating, deleting, and modifying alarms including annunciation and routing.
3. Creating, deleting, and modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
4. Creating, deleting, and modifying reports.
5. Creating, deleting, and modifying points.
6. Creating, deleting, and modifying programming including ability to edit control programs offline.
7. Creating, deleting, and modifying system graphics and other types of displays.
8. Adding DDC controllers and other network communication devices such as gateways and routers.
9. Adding operator workstations.
10. Performing DDC system checkout and diagnostic procedures.
11. Performing DDC controllers operation and maintenance procedures.
12. Performing operator workstation operation and maintenance procedures.
13. Configuring DDC system hardware including controllers, workstations, communication devices, and I/O points.
14. Maintaining, calibrating, troubleshooting, diagnosing, and repairing hardware.
15. Adjusting, calibrating, and replacing DDC system components.

O. Training Content for System Managers and Administrators:

1. DDC system software maintenance and backups.
2. Uploading, downloading, and offline archiving of all DDC system software and databases.
3. Interface with Project-specific, third-party operator software.
4. Understanding password and security procedures.
5. Adding new operators and making modifications to existing operators.
6. Operator password assignments and modification.
7. Operator authority assignment and modification.
8. Workstation data segregation and modification.

P. Video of Training Sessions:

1. Provide digital video and audio recording of each training session. Create separate recording file for each session.
2. Stamp each recording file with training session number, session name, and date.
3. Provide Owner with **[two]** copies of digital files on cloud and flash drives for later reference and for use in future training.
4. Owner retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION 230923

SECTION 230923.11 - CONTROL VALVES

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 control valves and actuators for DDC systems.
- B. Related Requirements:
 - 1. Section 230923 "Direct Digital Control (DDC) System for HVAC" control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993.11 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.11.

1.3 DEFINITIONS

- A. Cv: Design valve coefficient.
- B. DDC: Direct-digital control.
- C. NBR: Nitrile butadiene rubber.
- D. PTFE: Polytetrafluoroethylene
- E. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.

3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation, operation, and maintenance instructions, including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and[**mounting**] details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include diagrams for pneumatic signal and main air tubing.

C. Delegated-Design Submittal:

1. Schedule and design calculations for control valves and actuators, including the following:
 - a. Flow at project design and minimum flow conditions.
 - b. Pressure differential drop across valve at project design flow condition.
 - c. Maximum system pressure differential drop (pump close-off pressure) across valve at project minimum flow condition.
 - d. Design and minimum control valve coefficient with corresponding valve position.
 - e. Maximum close-off pressure.
 - f. Leakage flow at maximum system pressure differential.
 - g. Torque required at worst case condition for sizing actuator.
 - h. Actuator selection indicating torque provided.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Control valve installation location shown in relationship to room, duct, pipe, and equipment.
2. Size and location of wall access panels for control valves installed behind walls.
3. Size and location of ceiling access panels for control valves installed above inaccessible ceilings.

1.6 CLOSEOUT SUBMITTALS

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

PART 2 - PRODUCTS

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. Backup Power Source: Systems and equipment served by a backup power source shall have associated control valve actuators served from a backup power source.
- F. Environmental Conditions:
 - 1. Provide electric control valve actuators, with protective enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Electric control valve actuators not available with integral enclosures, complying with requirements indicated, shall be housed in protective secondary enclosures.
 - a. Hazardous Locations: Explosion-proof rating for condition.
- G. Determine control valve sizes and flow coefficients by ISA 75.01.01.
- H. Control valve characteristics and rangeability shall comply with ISA 75.11.01.
- I. Selection Criteria:
 - 1. Control valves shall be suitable for operation at following conditions:
 - a. Chilled Water.
 - b. Condenser Water.
 - c. Heat Recovery.
 - d. Heating Hot Water.
 - e. Steam.
 - 2. Control valve shutoff classifications shall be FCI 70-2, Class IV or better unless otherwise indicated.
 - 3. Valve pattern, three-way or straight through, shall be as indicated on Drawings.
 - 4. Modulating straight-through pattern control valves shall have equal percentage flow-throttling characteristics unless otherwise indicated.
 - 5. Modulating three-way pattern water valves shall have linear flow-throttling characteristics. The total flow through the valve shall remain constant regardless of the valve's position.
 - 6. Modulating butterfly valves shall have [**linear**] [**or**] [**equal percentage**] flow-throttling characteristics.

7. Fail positions unless otherwise indicated:
 - a. Chilled Water: **[Close]**.
 - b. Condenser Water: **[Close]**.
 - c. Heat Recovery: **[Close]**.
 - d. Heating Hot Water: **[Close]** .
 - e. Steam: **[Close]**.
8. Globe-type control valves shall pass the design flow required with not more than 95 percent of stem lift unless otherwise indicated.
9. Rotary-type control valves, such as ball and butterfly valves, shall have Cv falling between 65 and 75 degrees of valve full open position and minimum valve Cv between 15 and 25 percent of open position.
10. Selection shall consider viscosity, flashing, and cavitation corrections.
11. Valves shall have stable operation throughout full range of operation, from design to minimum Cv.
12. Minimum Cv shall be calculated at **[10]** percent of design flow, with a coincident pressure differential equal to the system design pump head.
13. In water systems, select modulating control valves at terminal equipment for a design Cv based on a pressure drop of **[5 psig (34 kPa)]** at design flow unless otherwise indicated.
14. Modulating valve sizes for steam service shall provide a pressure drop at design flow equal to lesser of the following:
 - a. **[50]** percent of the valve inlet pressure.
 - b. **[50]** percent of the absolute steam pressure at the valve inlet.
15. Two-position control valves shall be line size unless otherwise indicated.
16. In water systems, use ball- or globe-style control valves for two-position control for valves **NPS 2 (DN 50)** and smaller and butterfly style for valves larger than **NPS 2 (DN 50)**.
17. In steam systems, use ball- or globe-style control valves regardless of size.

2.2 BALL-STYLE CONTROL VALVES

A. Ball Valves with Single Port and Characterized Disk:

1. Pressure Rating for **NPS 1 (DN 25)** and Smaller: Nominal 600 WOG.
2. Pressure Rating for **NPS 1-1/2 (DN 38)** through **NPS 2 (DN 50)**: Nominal 400 WOG.
3. Close-off Pressure: **200 psig (1379 kPa)**.
4. Process Temperature Range: **Zero to 212 deg F (Minus 18 to plus 100 deg C)**.
5. Body and Tail Piece: Cast bronze ASTM B61, ASTM B62, ASTM B584, or forged brass with nickel plating.
6. End Connections: Threaded (NPT) ends.
7. Ball: **[Chrome-plated brass or bronze] [or] [300 series stainless steel]**.
8. Stem and Stem Extension:
 - a. Material to match ball.
 - b. Blowout-proof design.
 - c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.

9. Ball Seats: Reinforced PTFE.
 10. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
 11. Flow Characteristic: Equal percentage.
- B. Ball Valves with Two Ports and Characterized Disk:
1. Pressure Rating for **NPS 1 (DN 25)** and Smaller: Nominal 600 WOG.
 2. Pressure Rating for **NPS 1-1/2 (DN 38)** through **NPS 2 (DN 50)**: Nominal 400 WOG.
 3. Close-off Pressure: **200 psig (1379 kPa)**.
 4. Process Temperature Range: **Zero to 212 deg F (Minus 18 to plus 100 deg C)**.
 5. Body and Tail Piece: Cast bronze ASTM B61, ASTM B62, ASTM B584, or forged brass with nickel plating.
 6. End Connections: Threaded (NPT) ends.
 7. Ball: [**Chrome-plated brass or bronze**] [**or**] [**300 series stainless steel**].
 8. Stem and Stem Extension:
 - a. Material to match ball.
 - b. Blowout-proof design.
 - c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.
 9. Ball Seats: Reinforced PTFE.
 10. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
 11. Flow Characteristics for A-Port: Equal percentage.
 12. Flow Characteristics for B-Port: Modified for constant common port flow.
 - a. .
- C. Ball Valves with Segmented Ball, Three-Way Pattern:
1. Arrangement: Two single-port valves mated to a fabricated tee with interconnecting mechanical linkage.
 2. Performance:
 - a. Process Temperature Rating: **Minus 20 to plus 450 deg F (Minus 29 to plus 232 deg C)**.
 - b. ASME B16.34, [**Class 300**].
 - c. Leakage: FCI 70-2, Class IV.
 - d. Rangeability: 300 to 1.
 - e. Rotation: Zero to 90 degrees.
 - f. Equal percentage flow characteristic.
 3. Face-to-Face Dimensions: ASME B16.10.
 4. Valves **NPS 3 (DN 80)** through **NPS 6 (DN 150)**: Flanged ends suitable for mating to ASME B16.5 flanges.
 5. Body: [**Carbon**] [**or**] [**stainless**] steel.
 6. Ball and Shaft: Stainless steel.
 7. Shaft and Segmented Ball: Pinned and welded.

8. Ball Seat: Graphite.
9. Packing: PTFE V-rings and graphite packing follower.
10. Replaceable seat, ball, and shaft packing.
11. Label each valve with following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Flow directional arrow.

D. Pressure-Independent Ball Valves **NPS 2 (DN 50)** and Smaller:

1. Performance:
 - a. Pressure Rating: **600 psig (4137 kPa)** for **NPS 1 (DN 25)** and **400 psig (2528 kPa)** for **NPS 1-1/2 and NPS 2 (DN 38 and DN 50)**.
 - b. Close-off pressure of **200 psig (1379 kPa)**.
 - c. Process Temperature Range: Between **zero to 212 deg F (minus 18 to plus 100 deg C)**.
 - d. Rangeability: 100 to 1.
2. Integral Pressure Regulator: Located upstream of ball to regulate pressure, to maintain a constant pressure differential while operating within a pressure differential range of **5 to 50 psig (34 to 345 kPa)**.
3. Body: Forged brass, nickel plated, and with threaded ends.
4. Ball: Chrome-plated brass.
5. Stem and Stem Extension: Chrome-plated brass, blowout-proof design.
6. Stem sleeve or other approved means to allow valve to be opened and closed without damaging field-applied insulation and insulation vapor barrier seal.
7. Ball Seats: Reinforced PTFE.
8. Stem Seal: Reinforced PTFE packing ring stem seal with threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if equivalent cycle endurance can be achieved.
9. Flow Characteristic: Equal percentage.

2.3 BUTTERFLY-STYLE CONTROL VALVES

A. Commercial-Grade, Two-Way Butterfly Valves:

1. Performance:
 - a. Bi-directional bubble tight shutoff at **250 psig (1724 kPa)**.
 - b. Comply with MSS SP-67 or MSS SP-68.
 - c. Rotation: Zero to 90 degrees.
 - d. Linear or modified equal percentage flow characteristic.
2. Body: Cast iron ASTM A126, Class B, ductile iron ASTM A536 or cast steel ASTM A216/A216M WCB fully lugged, suitable for mating to ASME B16.5 flanges.
3. Disc: 316 stainless steel.
4. Shaft: 316 or 17-4 PH stainless steel.
5. Seat: Reinforced EPDM or reinforced PTFE with retaining ring.
6. Shaft Bushings: Reinforced PTFE or stainless steel.

7. Replaceable seat, disc, and shaft bushings.
8. Corrosion-resistant nameplate indicating:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Body and trim materials.
 - d. Flow arrow.

B. Commercial-Grade, Three-Way Butterfly Valves:

1. Arrangement: Two valves mated to a fabricated tee with interconnecting mechanical linkage.
2. Performance:
 - a. Bi-directional bubble tight shutoff at **250 psig (1724 kPa)**.
 - b. Comply with MSS SP-67 or MSS SP-68.
 - c. Rotation: Zero to 90 degrees.
 - d. Linear or modified equal percentage flow characteristic.
3. Body: Cast iron ASTM A126, Class B, ductile iron ASTM A536 or cast steel ASTM A216/A216M WCB fully lugged, suitable for mating to ASME B16.5 flanges.
4. Disc: 316 stainless steel.
5. Shaft: 316 or 17-4 PH stainless steel.
6. Seat: Reinforced EPDM or reinforced PTFE seat with retaining ring.
7. Shaft Bushings: Reinforced PTFE or stainless steel.
8. Replaceable seat, disc, and shaft bushings.
9. Corrosion-resistant nameplate indicating:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Body and trim materials.
 - d. Flow arrow.

2.4 GLOBE-STYLE CONTROL VALVES

A. General Globe-Style Valve Requirements:

1. Globe-style control valve body dimensions shall comply with ISA 75.08.01.
2. Construct the valves to be serviceable from the top.
3. For cage guided valves, trim shall be field interchangeable for different valve flow characteristics, such as equal percentage, linear, and quick opening.
4. Reduced trim for one nominal size smaller shall be available for industrial valves **NPS 1 (DN 25)** and larger.
5. Replaceable seats and plugs.
6. Furnish each control valve with a corrosion-resistant nameplate indicating the following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body and trim size.
 - c. Arrow indicating direction of flow.

- B. Two-Way Globe Valves **NPS 2 (DN 50)** and Smaller:
1. Globe Style: Single port.
 2. Body: Cast bronze or forged brass with ASME B16.5, Class 250 rating.
 3. End Connections: Threaded.
 4. Bonnet: Screwed.
 5. Packing: PTFE V-ring.
 6. Plug: Top guided.
 7. Plug, Seat, and Stem: **[Brass] [or] [stainless steel]**.
 8. Process Temperature Range: **35 to 248 deg F (2 to 120 deg C)**.
 9. Ambient Operating Temperature: **35 to 150 deg F (2 to 65 deg C)**.
 10. Leakage: FCI 70-2, Class IV.
 11. Rangeability: 25 to 1.
 12. Equal percentage flow characteristic.
- C. Three-Way Globe Valves **NPS 2 (DN 50)** and Smaller:
1. Globe Style: Mix flow pattern.
 2. Body: Cast bronze or forged brass with ASME B16.5, Class 250 rating.
 3. End Connections: Threaded.
 4. Bonnet: Screwed.
 5. Packing: PTFE V-ring.
 6. Plug: Top guided.
 7. Plug, Seat, and Stem: **[Brass] [or] [stainless steel]**.
 8. Process Temperature Range: **35 to 248 deg F (2 to 120 deg C)**.
 9. Ambient Operating Temperature: **35 to 150 deg F (2 to 65 deg C)**.
 10. Leakage: FCI 70-2, Class IV.
 11. Rangeability: 25 to 1.
 12. Linear flow characteristic.
- D. Two-Way Globe Valves **NPS 2-1/2 to NPS 6 (DN 65 to DN 150)**:
1. Globe Style: Single port.
 2. Body: Cast iron complying with ASME B61.1, Class 125.
 3. End Connections: Flanged, suitable for mating to ASME B16.5, Class 150 flanges.
 4. Bonnet: Bolted.
 5. Packing: PTFE cone-ring.
 6. Plug: Top or bottom guided.
 7. Plug, Seat, and Stem: Brass or stainless steel.
 8. Process Temperature Rating: **35 to 281 deg F (2 to 138 deg C)**.
 9. Leakage: 0.1 percent of maximum flow.
 10. Rangeability: Varies with valve size between 6 and 10 to 1.
 11. Modified linear flow characteristic.
- E. Three-Way Globe Valves **NPS 2-1/2 to NPS 6 (DN 65 to DN 150)**:
1. Globe Style: Mix flow pattern.
 2. Body: Cast iron complying with ASME B61.1, Class 125.
 3. End Connections: Flanged suitable for mating to ASME B16.5, Class 150 flanges.
 4. Bonnet: Bolted.
 5. Packing: PTFE cone-ring.
 6. Plug: Top or bottom guided.
 7. Plug, Seat, and Stem: Brass or stainless steel.
 8. Process Temperature Rating: **35 to 281 deg F (2 to 138 deg C)**.
 9. Leakage: 0.1 percent of maximum flow.

10. Rangeability: Varies with valve size between 6 and 10 to 1.
11. Modified linear flow characteristic.

2.5 SOLENOID VALVES

A. Description:

1. Action: Either normally open or normally closed in the event of electrical power failure as required by the application.
2. Size to close against the system pressure.
3. Manual override capable.
4. Heavy-duty assembly.
5. Body: **[Brass] [or] [stainless steel]**.
6. Seats and Discs: NBR or PTFE.
7. Solenoid Enclosure: NEMA 250, Type 4.

2.6 SELF-CONTAINED TEMPERATURE REGULATING VALVE

A. Description:

1. Self-contained and self-operated temperature regulating valve. Direct acting or reverse acting as required by application.
2. Direct Acting: A rise in temperature at the sensing bulb vaporizes some of the liquid in the bulb, forcing the remaining liquid through a capillary to apply pressure at the diaphragm, in turn closing the valve. The valve shall fail open.
3. Reverse Acting: A rise in temperature at the sensing bulb vaporizes some of the liquid in the bulb, forcing the remaining liquid through a capillary to apply pressure at the diaphragm, in turn opening the valve. The valve shall fail close.
4. Body: Carbon steel.
5. Trim and Seats: 300 series stainless steel.
6. Yoke: Cast iron.
7. Actuator: 300 series stainless steel.
8. End Connections: Threaded.
9. Capillary, Bulb, and Armor: 300 series stainless steel.
10. Thermal Fill Material: Match to the temperature range.
11. Thermowell: Type 316 stainless-steel thermowell sized to fit the bulb and pipe.

B. Operational Characteristics: Control flow from between 5 to 100 percent of rated capacity.

C. Interchangeable trim for one size smaller.

D. Valve Leakage: Comply with FCI 70-2, Class IV.

E. Temperature Range: Match application.

1. Drains from Hot Equipment to Sanitary Sewer System: 105 to 165 deg F (40 to 74 deg C).

- F. Valve Size: Size to pass the design flow required with not more than 95 percent of the stem lift while operating at design pressure.

2.7 PNEUMATIC CONTROL VALVE ACTUATORS

- A. Actuators for Hydronic Control Valves: Shutoff against system pump shutoff head.
- B. Actuators for Steam Control Valves: Shutoff against [1.5] times steam design pressure.
- C. Position indicator and graduated scale on each actuator.
- D. Provide diaphragm action (air-to-open, air-to-close), as required by the sequence of operation, in the event of air supply failure.
- E. For each modulating control valve, provide a positive positioner with the valve actuator. The positioners shall operate on a 3- to 15-psig (21- to 103-kPa) input signal unless otherwise required to satisfy control sequences of operation. Integrally mount each positioner with an air regulator, air set, and gauges for supply, input and output. The positioner shall have the following performance characteristics:
 - 1. Linearity: Plus or minus 1 percent of the output signal span.
 - 2. Hysteresis: 0.5 percent of span.
- F. Diaphragms shall be replaceable.
- G. Actuator Construction:
 - 1. Cast-iron or steel diaphragm casing and plate. Cast aluminum is acceptable on valves NPS 4 (DN 100) and smaller.
 - 2. Cast iron or steel yoke. Cast aluminum is acceptable on valves NPS 4 (DN 100) and smaller.
 - 3. Reinforced synthetic rubber or nitrile diaphragm.
 - 4. Steel or steel alloy spring, stem, and spring adjuster.
- H. Rate actuators for not less than 1.2 times the main air pressure to the valve, minimum 30 psig (207 kPa).

2.8 ELECTRIC AND ELECTRONIC CONTROL VALVE ACTUATORS

- A. Actuators for Hydronic Control Valves: Capable of closing valve against system pump shutoff head.
- B. Actuators for Steam Control Valves: Shutoff against [1.5] times steam design pressure.
- C. Position indicator and graduated scale on each actuator.
- D. Type: Motor operated, with or without gears, electric and electronic.
- E. Voltage: [Voltage selection delegated to professional designing control system].

- F. Deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
- G. Function properly within a range of 85 to 120 percent of nameplate voltage.
- H. Construction:
 - 1. For Actuators Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
 - 2. For Actuators from 100 to 400 W: Gears ground steel, oil immersed, shaft hardened steel running in bronze, copper alloy or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel or cast-aluminum housing.
 - 3. For Actuators Larger Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.
- I. Field Adjustment:
 - 1. Spring Return Actuators: Easily switchable from fail open to fail closed in the field without replacement.
 - 2. Gear Type Actuators: External manual adjustment mechanism to allow manual positioning when the actuator is not powered.
- J. Two-Position Actuators: Single direction, spring return or reversing type.
- K. Modulating Actuators:
 - 1. Operation: Capable of stopping at all points across full range, and starting in either direction from any point in range.
 - 2. Control Input Signal:
 - a. Three Point, Tristate, or Floating Point: Clockwise and counter-clockwise inputs. One input drives actuator to open position and other input drives actuator to close position. No signal of either input remains in last position.
 - b. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for [~~zero-~~ to 10-] V dc [~~and~~] [~~4-~~ to 20-mA] signals.
 - c. Pulse Width Modulation (PWM): Actuator drives to a specified position according to pulse duration (length) of signal from a dry contact closure, triac sink, or source controller.
 - d. Programmable Multi-Function:
 - 1) Control Input, Position Feedback, and Running Time: Factory or field programmable.
 - 2) Diagnostic: Feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
 - 3) Service Data: Include, at a minimum, number of hours powered and number of hours in motion.

L. 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.

M. 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.

N. 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.

O. Valve Attachment:

1. Unless otherwise required for valve interface, provide an actuator designed to be directly coupled to valve shaft without the need for connecting linkages.
2. Attach actuator to valve drive shaft in a way that ensures maximum transfer of power and torque without slippage.
3. Bolt and set screw method of attachment is acceptable only if provided with at least two points of attachment.

P. Temperature and Humidity:

1. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of [minus 20 to plus 120 deg F (minus 29 to plus 49 deg C)] .
2. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from [5 to 95] percent relative humidity, non-condensing.

Q. Enclosure:

1. Suitable for ambient conditions encountered by application.
2. NEMA 250, Type 2 for indoor and protected applications.
3. NEMA 250, Type 4 or Type 4X for outdoor and unprotected applications.
4. Provide actuator enclosure with heater and control where required by application.

R. Stroke Time:

1. Operate valve from fully closed to fully open within **[15]** seconds.
2. Operate valve from fully open to fully closed within **[15]** seconds.
3. Move valve to failed position within **[5]** seconds.
4. Select operating speed to be compatible with equipment and system operation.

S. 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 valves installed in piping to verify actual locations of piping connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CONTROL VALVE APPLICATIONS

A. Control Valves:

1. Select from valves specified in "Control Valves" Article to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.
2. Two-Way Applications Controlled by Flow: **[Ball valves with single port and characterized disk] [Butterfly-style valves, commercial-grade, two-way valves]**.
3. Two-Way Applications Controlled by Pressure: **[Pressure-independent ball valves]**.
4. Two-Way Applications Controlled by Temperature: **[Ball valves with single port and characterized disk] [Solenoid valves] [Self-contained temperature regulating valves]**.
5. Three Way, Controlled by Temperature: **[Ball valves with segmented ball, three-way pattern] [Butterfly-style valves, commercial-grade, three-way valves] [Globe-style, three-way valves]**.
6. Steam System, Two Way, Controlled by Temperature: **[Ball valves with single port and segmented ball] [Globe-style, two-way valves]** .

3.3 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy most stringent requirements indicated.

- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Properly support instruments, tubing, piping, wiring, and conduits to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a force.
- D. Provide ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- E. Firestop penetrations made in fire-rated assemblies and seal penetrations made in acoustically rated assemblies.
- F. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that will cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- G. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- H. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they will be subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - 3. Use Type 316 stainless-steel tubing and fittings when in contact with a corrosive environment.
 - 4. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 5. Where control devices are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."

- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 CONTROL VALVES

- A. Install pipe reducers for valves smaller than line size. Position reducers as close to valve as possible but at distance to avoid interference and impact to performance. Install with manufacturer-recommended clearance.
- B. Install flanges or unions to allow drop-in and -out valve installation.
- C. Where indicated, install control valve with three-valve bypass manifold to allow for control valve isolation and removal without interrupting system flow by providing manual throttling valve in bypass pipe.
- D. Install drain valves in piping upstream and downstream of each control valve installed in a three-valve manifold and for each control valve larger than [NPS 2 (DN 50)].
- E. Install pressure temperature taps in piping upstream and downstream of each control valve larger than [NPS 1 (DN 25)].
- F. Valve Orientation:
 - 1. Where possible, install globe and ball valves installed in horizontal piping with stems upright and not more than 15 degrees off of vertical, not inverted.
 - 2. Install valves in a position to allow full stem movement.
 - 3. Where possible, install butterfly valves that are installed in horizontal piping with stems in horizontal position and with low point of disc opening with direction of flow.
- G. Clearance:
 - 1. Locate valves for easy access and provide separate support of valves that cannot be handled by service personnel without hoisting mechanism.
 - 2. Install valves with at least 12 inches (300 mm) of clear space around valve and between valves and adjacent surfaces.
- H. Threaded Valves:
 - 1. Note internal length of threads in valve ends, and proximity of valve internal seat or wall, to determine how far pipe should be threaded into valve.
 - 2. Align threads at point of assembly.
 - 3. Apply thread compound to external pipe threads, except where dry seal threading is specified.
 - 4. Assemble joint, wrench tight. Apply wrench on valve end as pipe is being threaded.

I. Flanged Valves:

1. Align flange surfaces parallel.
2. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets as flat and parallel as possible. Use suitable lubricants on bolt threads. Tighten bolts gradually and uniformly with a torque wrench.

3.6 CONNECTIONS

- A. Connect electrical devices and components to electrical grounding system. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with valve identification on valve[**and on face of ceiling directly below valves concealed above ceilings**].

3.8 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.
- C. Polish glossy surfaces to a clean shine.

3.9 CHECKOUT PROCEDURES

- A. Control Valve Checkout:
1. Check installed products before continuity tests, leak tests, and calibration.
 2. Check valves for proper location and accessibility.
 3. Check valves for proper installation for direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
 4. For pneumatic products, verify air supply for each product is properly installed.
 5. For pneumatic valves, verify that pressure gauges are provided in each air line to valve actuator and positioner.
 6. Verify that control valves are installed correctly for flow direction.
 7. Verify that valve body attachment is properly secured and sealed.
 8. Verify that valve actuator and linkage attachment are secure.
 9. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
 10. Verify that valve ball, disc, and plug travel are unobstructed.

11. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.

3.10 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed back to 100 percent open.
- B. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed, and 100 percent open at proper air pressures.
- C. Check and document open and close cycle times for applications with a cycle time of less than 30 seconds.
- D. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

END OF SECTION 230923.11

SECTION 230923.14 - FLOW INSTRUMENTS

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. Airflow measurement stations and sensors.
2. Airflow switches.
3. Airflow transmitters.
4. Liquid flow meters.
5. Liquid flow sensors (primary elements).
6. Liquid flow switches.
7. Liquid flow transmitters.

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 230993.11 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.14.

1.3 DEFINITIONS

- A. Ethernet: Local area network based on IEEE 802.3 standards.
- B. FEP: Fluorinated ethylene propylene.
- C. HART: Highway addressable remote transducer protocol is the global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bi-directional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from technician's hand-held device or laptop to a plant's process control, asset management, safety, or other system using any control platform.
- D. PEEK: Polyetheretherketone.
- E. PTFE: Polytetrafluoroethylene.
- F. PPS: Polyphenylene sulfide.

- G. RS-485: A TIA standard for multipoint communications using two twisted pairs.
- H. RTD: Resistance temperature detector.
- I. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.

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.
 - 5. Product certificates.
- B. Sustainable Design Submittals:
- C. 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. Number-coded identification system for unique identification of wiring, cable, and tubing ends.
- D. Delegated Design Submittal:
 - 1. Schedule and design calculations for flow instruments, including the following.
 - a. Flow at Project design and minimum flow conditions.
 - b. Pressure drop at Project design and minimum flow conditions.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Certificates: For each product requiring a certificate.
- B. Product Test Reports: For each product, for tests performed by [**manufacturer and witnessed by a qualified testing agency**]

1.6 CLOSEOUT SUBMITTALS

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

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. Provide parts, as indicated by manufacturer's recommended parts list, for product operation during **[two]** year period following warranty period.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Select and size products to achieve specified performance requirements.
- B. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 GENERAL REQUIREMENTS FOR FLOW INSTRUMENTS

- A. Air sensors and transmitters shall have an extended range of **[10]** percent above Project design flow and **[10]** percent below minimum Project flow to signal abnormal flow conditions and to provide flexibility for changes in operation.
- B. Liquid and steam sensors, meters, and transmitters shall have an extended range of **[10]** percent above Project design flow and **[10]** percent below Project minimum flow to signal abnormal flow conditions and to provide flexibility for changes in operation.
- C. Source Limitations: For flow instruments, obtain products from single source from single manufacturer.

2.3 AIRFLOW MEASUREMENT STATIONS AND SENSORS

- A. Performance Requirements:
 - 1. Adjustable for changes in system operational parameters.
 - 2. Airflow Sensor and Transmitter Range: Extended range of **[10]** percent above Project design flow and **[10]** percent below minimum Project flow to signal abnormal flow conditions.
 - 3. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
 - a. Product certificates are required.

B. Thermal Airflow Measurement Stations:

1. Common Performance Requirements:

- a. Provide stations that are adjustable for changes in system operational parameters.
- b. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
- c. Thermal airflow stations with one or more sensor nodes mounted in a probe, and a remotely mounted microprocessor-based transmitter at each measurement location.
- d. Sensor Nodes: One self-heated and one zero-power bead-in-glass thermistor, using the principle of thermal dispersion.
- e. Airflow Rate and Temperature of Each Sensor: Equally weighted and averaged by the transmitter prior to output.
- f. Sensor-Node and Probe Assemblies:

- 1) Sensor-Node Construction: Two bead-in-glass, hermetically sealed thermistors potted in a marine-grade waterproof epoxy with sensor housings constructed of glass-filled polypropylene. Construct with only the thermistor located within the sensing node and all other electronic components outside the airstream. Epoxy- or glass-encapsulated chip thermistors or devices with exposed leads are not allowed. Devices that use epoxy- or glass-encapsulated chip thermistors, or electronics in the airstream, are unacceptable. Devices with exposed leads are unacceptable.
- 2) Store sensor-node airflow and temperature calibration data in a serial memory chip, in the cable connecting plug. Stored data does not require matching or adjustments to the transmitter in the field.
- 3) Sensing-Node Temperature Accuracy: Within **0.15 deg F (0.08 deg C)** over an operating range of **minus 20 to plus 160 deg F (minus 28.9 to plus 71.1 deg C)** and humidity range of 0 to 100 percent RH.
- 4) Sensor-Probe Mounting Bracket Construction: Type 304 stainless steel.
- 5) Internal Probe Wiring: Kynar-coated copper between the connecting cable and sensor nodes. PVC-jacketed wiring is unacceptable.
- 6) Internal Probe Wiring Connections: Solder joints and spot welds, sealed and protected from the elements, so that direct exposure to water will not affect instrument operation. Connectors within the probe, of any type, are unacceptable. Printed circuit boards within the probe are unacceptable.
- 7) Sensor-Probe Jacket: Integral, FEP jacket, plenum-rated CMP/CL2P, UL/cUL-listed cable, rated for exposures from **minus 67 to plus 392 deg F (minus 55 to plus 200 deg C)**, and for continuous and direct UV exposure. Plenum-rated PVC jacket cables are unacceptable.
- 8) Sensor-Probe Cable Connector Plug: Gold-plated pins for connection to the transmitter.

g. Transmitter Features and Functions:

- 1) High and/or low airflow alarm with user-defined set point and percent of set-point tolerance.
- 2) Manual or automatic alarm reset, and low-limit cutoff value may be selected to disable the alarm.
- 3) Alarm delay function, field defined.

- 4) Sensor-node malfunction via the system status alarm and ignore the sensor node that is in a fault condition.
 - 5) Field configuration, diagnostics, and field output adjustment wizard that allow for a one- or two-point field adjustment to factory calibration for installations that require adjustment.
 - 6) Automatic reset after power disruption, transients, and brown-outs through a watchdog timer circuit.
 - 7) Operating temperature range of **minus 20 to plus 120 deg F (minus 28.9 to plus 48.9 deg C)** and humidity range of 5 to 95 percent RH.
 - 8) Electrical Power Requirement: 24 V ac (between 22.8 and 26.4 V ac under load) at 20 VA maximum, using a switching power supply that is overcurrent and overvoltage protected.
 - 9) Printed Circuit Board Interconnects: Gold-plated edge fingers, receptacle plug pins, and printed circuit board test points.
 - 10) Printed Circuit Boards: Electroless nickel immersion gold (ENIG) plated.
 - 11) Integrated Circuitry: Temperature-rated, industrial-grade. Commercial-grade integrated circuitry is not acceptable.
 - 12) Integration Buffers: Separate integration buffers for display of airflow output, airflow signal output (analog and network), and individual sensor output (IR-interface).
2. For Air-Ducted/Plenum:
- a. Airflow Station Performance:
 - 1) Independent processing of up to **[16]** separately wired sensor-node assemblies.
 - 2) Accuracy: Within 3 percent of reading for ducted applications, and within 5 percent of reading for non-ducted applications, when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of **0 to 5000 fpm (0 to 25.4 m/s)**.
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Provide the number of independent sensor nodes as follows:
 - a) For Duct/Plenum Area up to **0.5 sq. ft. (0.046 sq. m)**: One.

- b) For Duct/Plenum Area Greater Than 0.5 through 1.0 sq. ft. (0.046 through 0.092 sq. m): Two.
 - c) For Duct/Plenum Area Greater Than 2.0 through 4.0 sq. ft. (0.186 through 0.372 sq. m): Six.
 - d) For Duct/Plenum Area Greater Than 4.0 through 8.0 sq. ft. (0.372 through 0.743 sq. m): Eight.
 - e) For Duct/Plenum Area Greater Than 8.0 through 12.0 sq. ft. (0.743 through 1.11 sq. m): 12.
 - f) For Duct/Plenum Area Greater Than 12.0 through 14.0 sq. ft. (1.11 through 1.30 sq. m): 14.
 - g) For Duct/Plenum Area Greater Than 14.0 sq. ft. (1.30 sq. m): 16.
- 4) For an aspect ratio of 1.5 or less, and an area of 25 sq. ft. (2.32 sq. m) or greater, four probes are required.
 - 5) Sensor-Probe Construction: [**Type 316 stainless steel tube**], with each sensor probe containing one or more independently wired sensing nodes.

c. Transmitter:

- 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
- 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC116 Transmitter: Two field-selectable [0-to 10-V dc,] [or] [4- to 20-mA,] scalable, isolated, overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - b) Model GTM116 Transmitter: Two field-selectable [0- to 10-V dc,] [or] [4- to 20-mA,] scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and

individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- c) Model GTL116 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
- d) Model GTD116 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.

3. For Air-Ducted/Plenum - Duct Size **2 sq. ft. (0.18 sq. m)** or Less:

a. Airflow Station Performance:

- 1) Independent processing of up to four separately wired sensor-node assemblies.
- 2) Accuracy: Within 3 percent of reading for ducted applications, and within 5 percent of reading for non-ducted applications, when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.

b. Sensor-Node and Probe Assemblies:

- 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
- 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of **0 to 5000 fpm (0 to 25.4 m/s)**.
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
- 3) Provide the number of independent sensor nodes as follows:
 - a) For Duct/Plenum Area up to **0.5 sq. ft. (0.046 sq. m)**: One.
 - b) For Duct/Plenum Area Greater Than **0.5 through 1.0 sq. ft. (0.046 through 0.092 sq. m)**: Two.
 - c) For Duct/Plenum Area Greater Than **1.0 sq. ft. (0.092 sq. m)**: Four.
- 4) For probes less than **8 inches (203 mm)**, one sensor node/probe is required.
- 5) Sensor-Probe Construction: [**Type 316 stainless steel tube**], with each sensor probe containing one or more independently wired sensing nodes.

- c. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP, or Modbus RTU) field-selectable network connection.
 - 3) Model HTA104 Transmitter, Analog Capability: Two field-selectable **[0- to 10-V dc,] [or] [4- to 20-mA,]** scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm.
 - 4) Model HTAN104 Transmitter, Network Communications: The RS-485 (BACnet MS/TP or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
- 4. For Supply or Return Fan Array:
 - a. Airflow Station Performance:
 - 1) Independent processing of up to eight separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading under operating conditions, when installed in accordance with manufacturer's sensor density and placement guidelines, with no effect on fan performance. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of **0 to 10,000 fpm (0 to 50.8 m/s)**.
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Sensor-Probe Construction: One sensor node mounted on a Type 304 stainless steel block with two adjustable zinc-plated steel rods connected to Type 304 stainless steel pivoting mounting feet.
 - 4) Number of Independent Sensor Nodes, Fan Arrays (One to Eight Fans): One probe with one sensor node per probe in each fan inlet.

c. Transmitter:

- 1) Transmitter determines the average airflow rate and temperature of each fan. Startup firmware facilitates the setup of multiple fans and fan areas.
- 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC108 Transmitter: Two field-selectable [**0- to 10-V dc,**] [**or**] [**4- to 20-mA,**] scalable, isolated, overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - b) Model GTM108 Transmitter: Two field-selectable [[**0- to 10-V dc,**] [**or**] [**4- to 20-mA,**] scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - c) Model GTL108 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - d) Model GTD108 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.

5. For Supply or Return Fan, Single-Width Single-Inlet (SWSI) or Double-Width Double-Inlet (DWDI) Fans - Both Analog and Network Outputs:
- a. Airflow Station Performance:
 - 1) Independent processing of up to eight separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading under operating conditions, when installed in accordance with manufacturer's sensor density and placement guidelines, with no effect on fan performance. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of **0 to 10,000 fpm (0 to 50.8 m/s)**.
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Sensor-Probe Construction: One sensor node mounted on a Type 304 stainless steel block with two adjustable zinc-plated steel rods connected to Type 304 stainless steel pivoting mounting feet.
 - 4) Number of Independent Sensor Nodes, SWSI Fans, and DWDI Fans: Two probes with one sensor node per probe in each fan inlet.
 - c. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of each fan. Startup firmware facilitates the setup of multiple fans and fan areas.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC108 Transmitter: Two field-selectable **[0- to 10-V dc,]** **[or] [4- to 20-mA,]** scalable, isolated, overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a

Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- b) Model GTM108 Transmitter: Two field-selectable [**0- to 10-V dc,**] [**or**] [**4- to 20-mA,**] scalable, isolated, and overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - c) Model GTL108 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - d) Model GTD108 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.
6. For Supply or Return Fan, Single-Width Single-Inlet (SWSI) or Double-Width Double-Inlet (DWDI) Fans - Either Analog or Network Outputs:
- a. Airflow Station Performance:
 - 1) Independent processing of up to four separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading under operating conditions, when installed in accordance with manufacturer's sensor density and placement guidelines, with no effect on fan performance. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.

- 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of **0 to 10,000 fpm** (**0 to 50.8 m/s**).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - c. Sensor-Probe Construction: One sensor node mounted on a Type 304 stainless steel block with two adjustable zinc-plated steel rods connected to Type 304 stainless steel pivoting mounting feet.
 - d. Number of Independent Sensor Nodes, SWSI Fans, and DWDI Fans: Two probes with one sensor node per probe in each fan inlet.
 - e. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP or Modbus RTU) field-selectable network connection.
 - 3) Model HTA104 Transmitter, Analog Capability: Two field-selectable [**0- to 10-V dc,**] [**or**] [**4- to 20-mA,**] scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm.
 - 4) Model HTN104 Transmitter, Network Communications: The RS-485 (BACnet MS/TP or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
7. For Air Terminal Units:
8. Airflow Station Performance:
 - a. Independent processing of up to two separately wired sensor-node assemblies.
 - b. Accuracy: Within 3 percent of reading when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
9. Sensor-Node and Probe Assemblies:
 - a. Sensor-Node Calibration:
 - 1) Individually calibrated at a minimum of seven calibration points to NIST-traceable volumetric standards from **0 to 3000 fpm** (**0 to 15.2 m/s**).

- 2) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - b. Provide the number of independent sensor nodes as follows:
 - 1) For a Duct Diameter of **4 Inches (102 mm)**: One.
 - 2) For Duct Diameters **5 through 16 Inches (127 through 406 mm)**: Two.
 - c. Sensor-Probe Construction: [**Type 316 stainless steel tube**], with each sensor probe containing one or more independently wired sensing nodes.
10. Transmitter:
 - a. Transmitter determines the average airflow rate and temperature of all connected sensor nodes in an array for a single location.
 - b. User Interface: An alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP or Modbus RTU) field-selectable network connection.
 - c. Model EF-A Transmitter, Analog Capability: Two field-selectable [**0- to 10-V dc,**] scalable analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm.
 - d. Model EF-N Transmitter, Network Communications: The RS-485 (BACnet MS/TP or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
 - e. Contact Closure Relay: One dry contact relay with onboard jumper to drive a remote LED, rated for no less than 30 V dc or 24 V ac at 3 A maximum. User configurable as normally open or normally closed during set up.
11. For Packaged HVAC Units, **12.5 Tons (44.0 kW)** or Smaller:
 - a. Airflow Station Performance:
 - 1) Independent processing of up to two separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Sensor-Node Internal Wiring Connections: Sealed and protected from the elements and suitable for direct exposure to water. Devices with exposed leads are unacceptable.
 - 2) Sensor-Node Calibration:
 - a) Individually calibrated at a minimum of seven calibration points to NIST-traceable airflow standards from **0 to 3000 fpm (0 to 15.2 m/s)**.

- b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Provide the number of independent sensor nodes as follows:
 - a) For a Duct Diameter of **4 Inches (102 mm)**: One.
 - b) For Duct Diameters **5 through 16 Inches (127 through 406 mm)**: Two.
 - 4) Sensor-Probe Construction: Mill-finish, 6063 aluminum alloy tube, with each sensor probe containing one or more independently wired sensing nodes.
 - c. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of all connected sensor nodes in an array for a single location.
 - 2) User Interface: An alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP or Modbus RTU) field-selectable network connection.
 - 3) Model EF-A Transmitter, Analog Capability: Two field-selectable [**0- to 10-V dc,**] scalable analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm.
 - 4) Model EF-N Transmitter, Network Communications: RS-485 (BACnet MS/TP or Modbus RTU) network connection to provide average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
 - 5) Contact Closure Relay: One dry contact relay with onboard jumper to drive a remote LED, rated for no less than 30 V dc or 24 V ac at 3 A maximum. User configurable as normally open or normally closed during set up.
12. For Directional Airflow:
- a. Bi-directional airflow measurement station with temperature output and integral airflow alarming to determine the exfiltration or infiltration airflow rate, and its direction and temperature at each measurement location.
 - b. Bi-directional airflow, or equivalent differential pressure data, is provided to the BAS, with system status indication, configurable airflow alarm, and internal diagnostics routine.
 - c. Sensor-Node Calibration:
 - 1) Individually calibrated at a minimum of nine calibration points to NIST-traceable volumetric standards from **minus 3000 to plus 3000 fpm (minus 15.2 to plus 15.2 m/s)**.
 - 2) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Probe to Transmitter Cables: Integral, FEP jacket, plenum-rated CMP/CL2P, UL/cUL-listed cable, rated for exposures from **minus 67 to plus 392 deg F (minus 55 to plus 200 deg C)**, and UV tolerant, with terminal plug for connection to the remotely mounted transmitter.

d. Transmitter:

- 1) Transmitter determines the average airflow rate and temperature of all connected sensor nodes in an array for a single location.
- 2) User Interface: An alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP or Modbus RTU) field-selectable network connection.
- 3) Model EF-A Transmitter, Analog Capability: Two field-selectable **0- to 10-V dc,** scalable and protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature low and/or high airflow set-point alarm (user-defined) or system status alarm.
- 4) Model EF-N Transmitter, Network Communications: The RS-485 (BACnet MS/TP or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
- 5) Contact Closure Relay: One dry contact relay with onboard jumper to drive a remote LED, rated for no less than 30 V dc or 24 V ac at 3 A maximum. User configurable as normally open or normally closed during set up.

13. For Data Center Server Rack Airflow/Pressure and Temperature Monitor:

- a. Bi-directional airflow measurement station with temperature output and integral airflow alarming to determine the exfiltration or infiltration airflow rate, and its direction and temperature at each measurement location.
- b. Bi-directional airflow, or equivalent differential pressure data, is provided to the BAS, with system status indication, configurable airflow alarm, and internal diagnostics routines.
- c. Sensor-Node and Probe Assemblies:
 - 1) Sensor-Node Internal Wiring Connections: Sealed and protected from the elements and suitable for direct exposure to water. Devices with exposed leads are unacceptable.
 - 2) Sensor Node Calibration:
 - a) Individually calibrated at a minimum of nine calibration points to NIST-traceable volumetric standards from **minus 2000 to plus 2000 fpm (minus 10.2 to plus 10.2 m/s).**
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
- d. Probe to Transmitter Cables: Integral, FEP jacket, plenum-rated CMP/CL2P, UL/cUL-listed cable, rated for exposures from **minus 67 to plus 392 deg F (minus 55 to plus 200 deg C),** and UV tolerant, with terminal plug for connection to the remotely mounted transmitter. Plenum-rated PVC jacket cables are unacceptable.
- e. Transmitter:
 - 1) Integral Transmitter with Display: Mounted internally to the rack enclosure an integral, minimum 16-character LCD display capable of simultaneously displaying airflow and temperature, and capable of displaying individual airflow and temperature readings.

- 2) Transmitter Interface: Four-button interface for field configuration and diagnostics.
 - 3) Power Supply: On-off power switch, 110 V ac at 8 VA, fused and protected from overvoltage, overcurrent, and power surges. Provide dual independent and redundant power supplies.
 - 4) Network Interface: One isolated Ethernet network connection (simultaneously supporting field-selectable BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP protocols).
14. For Combination Control Damper and Airflow Station - Equal Area Method Distribution Pattern:
- a. Thermal airflow station and integral damper with two or more sensor nodes mounted in a probe, and a remotely mounted microprocessor-based transmitter at each measurement location. Sensor-node distribution pattern to be based on equal area method.
 - b. Airflow Station Performance:
 - 1) Independent processing of up to 16 separately wired sensor-node assemblies.
 - 2) Accuracy: Within 3 percent of reading for ducted applications, and within 5 percent of reading for non-ducted applications, when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - c. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 5000 fpm (0 to 25.4 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Provide the number of independent sensor nodes as follows:
 - a) For Damper Area up to 1.0 sq. ft. (0.092 sq. m): Two.
 - b) For Duct/Plenum Area Greater Than 1.0 through 4.0 sq. ft. (0.092 through 0.372 sq. m): Four.
 - c) For Duct/Plenum Area Greater Than 4.0 through 8.0 sq. ft. (0.372 through 0.743 sq. m): Six.
 - d) For Duct/Plenum Area Greater Than 8.0 through 12.0 sq. ft. (0.743 through 1.11 sq. m): Eight.
 - e) For Duct/Plenum Area Greater Than 12.0 through 16.0 sq. ft. (1.11 through 1.49 sq. m): 12.

- f) For Duct/Plenum Area Greater Than **16.0 sq. ft. (1.49 sq. m)**: 16.
- 4) Sensor Probe Construction: Gold-anodized, 6063 aluminum alloy tube with each sensor probe containing one or more independently wired sensing nodes.
- d. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC116 Transmitter: Two field-selectable **0- to 10-V dc,** [or] **4- to 20-mA,** scalable, isolated, overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - 3) Model GTM116 Transmitter: Two field-selectable **[0- to 10-V dc,] [or] [4- to 20-mA,]** scalable, isolated, and overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- 4) Model GTL116 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - 5) Model GTD116 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.
- e. Integral Control Damper and Sleeve:
- 1) Frame and Sleeve: Extruded 6063T5 aluminum with an integral damper frame.
 - a) Thickness: Not less than 0.080-inch (2.0-mm) thickness for each damper section.
 - b) Sleeve Depth: 15 inches (381 mm) for ducted applications and 18 inches (457 mm) for non-ducted applications including damper frame. Non-ducted applications include a 3-inch- (7.6-mm-) radius, aluminum entry flair.
 - c) Installation: Provide an additional 7 inches (178 mm) for non-ducted, 10 inches (254 mm) for ducted, applications between the downstream edge of an intake louver and the leading edge of the entry flair for outside air intake applications that are close coupled to intake louvers.
 - d) Leakage: The damper leakage shall not exceed 3 cfm/sq. ft. (15.2 L/s per sq. m) of face area against 1-inch wg (248.8-Pa) differential static pressure.
 - 2) Blades: Extruded 6063T5 aluminum airfoil blades not less than 0.060-inch (1.52-mm) thickness.
 - a) Blade Seals: Extruded EPDM.
 - b) Frame Seals: Extruded silicone secured in an integral slot within the aluminum extrusions.
 - c) Orientation: Parallel or opposed blade configuration as required by application.
 - 3) Bearings: Celcon inner bearing fixed to a 7/16-inch (11.1-mm) aluminum hexagon blade pin, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
 - 4) Linkage: Aluminum- and corrosion-resistant zinc-plated steel, complete with cup-point trunnion screws for a slip-proof grip, installed inside the frame.
 - 5) Control-Damper Actuator: Modulating, electronic, damper actuator of sufficient number and adequate size, factory mounted and tested. Control-damper actuators are specified in Section 230923.12 "Control Dampers."
15. For Combination Control Damper and Airflow Station - Modified Log Distribution Pattern:
- a. Thermal airflow station and integral damper with one or more sensor nodes mounted in a probe, and a remotely mounted microprocessor-based transmitter at each measurement location. Sensor node distribution pattern to be based on modified log Tchebycheff method.

b. Airflow Station Performance:

- 1) Independent processing of up to 16 separately wired sensor-node assemblies.
- 2) Accuracy: Within 3 percent of reading for ducted applications, and within 5 percent of reading for non-ducted applications, when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.

c. Sensor-Node and Probe Assemblies:

- 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
- 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 5000 fpm (0 to 25.4 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
- 3) Provide the number of independent sensor nodes as follows:
 - a) For Damper Area up to 1.0 sq. ft. (0.092 sq. m): Two.
 - b) For Duct/Plenum Area Greater Than 1.0 through 2.0 sq. ft. (0.092 through 0.185 sq. m): Four.
 - c) For Duct/Plenum Area Greater Than 2.0 through 4.0 sq. ft. (0.185 through 0.372 sq. m): Six.
 - d) For Duct/Plenum Area Greater Than 4.0 through 8.0 sq. ft. (0.372 through 0.743 sq. m): Eight.
 - e) For Duct/Plenum Area Greater Than 8.0 through 12.0 sq. ft. (0.743 through 1.11 sq. m): 12.
 - f) For Duct/Plenum Area Greater Than 12.0 through 14.0 sq. ft. (1.11 through 1.30 sq. m): 14.
 - g) For Duct/Plenum Area Greater Than 14.0 sq. ft. (1.49 sq. m): 16.
- 4) Sensor Probe Construction: Gold-anodized, 6063 aluminum alloy tube with each sensor probe containing one or more independently wired sensing nodes.

d. Transmitter:

- 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
- 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:

- a) Model GTC116 Transmitter: Two field-selectable [0- to 10-V dc,] [or] [4- to 20-mA,] scalable, isolated, overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - b) Model GTM116 Transmitter: Two field-selectable [0- to 10-V dc,] [or] [4- to 20-mA,] scalable, isolated, and overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - c) Model GTL116 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - d) Model GTD116 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.
- e. Integral Control Damper and Sleeve:
- 1) Frame and Sleeve: Extruded 6063T5 aluminum with an integral damper frame.
 - a) Thickness: Not less than 0.080-inch (2.0-mm) thickness for each damper section.

- b) Sleeve Depth: 13 inches (330 mm) for all applications including damper frame. Sleeve includes a 1-inch- (2.56-mm-) radius, aluminum entry flair.
 - c) Installation: Provide an additional 7 inches (178 mm) between the downstream edge of an intake louver and the leading edge of the entry flair for outside air intake applications that are close coupled to intake louvers.
 - d) Leakage: The damper leakage shall not exceed 3 cfm/sq. ft. (15.2 L/s per sq. m) of face area against 1-inch wg (248.8-Pa) differential static pressure.
 - 2) Blades: Extruded 6063T5 aluminum airfoil blades not less than 0.060-inch (1.52-mm) thickness.
 - a) Blade Seals: Extruded EPDM.
 - b) Frame Seals: Extruded silicone secured in an integral slot within the aluminum extrusions.
 - c) Orientation: Parallel or opposed blade configuration as required by application.
 - 3) Bearings: Celcon inner bearing fixed to a 7/16-inch (11.1-mm) aluminum hexagon blade pin, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
 - 4) Linkage: Aluminum- and corrosion-resistant zinc-plated steel, complete with cup-point trunnion screws for a slip-proof grip, installed inside the frame.
 - 5) Control-Damper Actuator: Modulating, electronic, damper actuator of sufficient number and adequate size, factory mounted and tested. Control-damper actuators are specified in Section 230923.12 "Control Dampers."
- 16. For Combination Backdraft Damper and Airflow Station:
 - a. Thermal airflow station with one or more sensor nodes mounted in a probe, and a remotely mounted microprocessor-based transmitter at each measurement location.
 - b. Airflow Station Performance:
 - 1) Independent processing of up to eight separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading under operating conditions, when installed in accordance with manufacturer's sensor density and placement guidelines, with no effect on fan performance. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - c. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.

- 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 10,000 fpm (0 to 50.8 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Sensor-Probe Construction: One sensor node mounted on a Type 304 stainless steel block with two adjustable zinc-plated steel rods connected to Type 304 stainless steel pivoting mounting feet.
 - 4) Number of Independent Sensor Nodes, Fan Arrays (One to Eight Fans): One probe with one sensor node per probe in each fan inlet.
- d. Transmitter:
- 1) Transmitter determines the average airflow rate and temperature of each fan. Startup firmware facilitates the setup of multiple fans and fan areas.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC108 Transmitter: Two field-selectable [0- to 10-V dc,] [or] [4- to 20-mA,] scalable, isolated, overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - b) Model GTM108 Transmitter: Two field-selectable [0- to 10-V dc,] [or] [4- to 20-mA,] scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of

transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- c) Model GTL108 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
- d) Model GTD108 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.

e. Integral Heavy-Duty Backdraft Damper:

- 1) Frame and Sleeve: Extruded 6063T5 aluminum with an integral damper frame.
 - a) Thickness and Depth: Not less than 0.080-inch (2.0-mm) thickness.
 - b) Sleeve Depth: 8 inches (457 mm), which act as an integrated sleeve. Optional 1-inch (7.6-mm) radius, aluminum entry flair.
 - c) Installation: Provide an additional 7 inches (178 mm) between the downstream edge of any components and leading edge of the damper frame or entry flare.
 - d) Leakage: The damper leakage shall not exceed 3 cfm/sq. ft. (15.2 L/s per sq. m) of face area against 1-inch wg (248.8-Pa) differential static pressure.
- 2) Blades: Extruded 6063T5 aluminum airfoil blades not less than 0.060-inch (1.52-mm) thickness.
 - a) Blade Seals: Extruded EPDM.
 - b) Frame Seals: Extruded silicone secured in an integral slot within the aluminum extrusions.
 - c) Orientation: Parallel configuration as required by application.
- 3) Bearings: Celcon inner bearing fixed to a 7/16-inch (11.1-mm) aluminum hexagon blade pin, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
- 4) Linkage: Aluminum- and corrosion-resistant zinc-plated steel, complete with cup-point trunnion screws for a slip-proof grip, installed inside the frame.

C. Pitot-Tube Airflow Sensor Station:

- 1. Description: Multiple total- and static-pressure sensors positioned at the center of equal area of the station cross section and interconnected by respective averaging manifolds.
 - a. Stations 4 sq. ft. (0.4 sq. m) and Smaller: One total-pressure sensor and one static-pressure sensor for every 16 sq. in. (103 sq. cm) of station area.
 - b. Stations Larger than 4 sq. ft. (0.4 sq. m): One total-pressure sensor and one static-pressure sensor for every 36 sq. in. (232 sq. cm) of station area.

2. Casing: Galvanized sheet steel at least **0.079 inch (2.0 mm)** thick with coating complying with ASTM A653/A653M, **G90 (Z275)**. Casings shall be stainless steel, **0.0781 inch (2.0 mm)** thick, when connected to stainless duct and aluminum, **0.063 inch (1.6 mm)** thick, when connected to aluminum duct.
 - a. Joints and Seams: Continuously weld. Clean galvanized areas damaged by welding and coat with aluminum paint.
 - b. Casing Depth: At least **8 inches (200 mm)**.
 - c. Casing Flanges: Outward flange, minimum flange face **1.5 inches (38 mm)**.
 - d. Casing Configuration and Size: Match shape (rectangular, round, flat oval) and same size as adjacent duct unless otherwise indicated.
 3. Include an open parallel cell air straightener or air equalizer honeycomb mechanically fastened to casing.
 - a. Construct straightener or equalizer from Type 3003 aluminum or Type 316 stainless steel, depending on casing material. Use stainless steel for units with stainless steel casings.
 4. Construct pressure sensor array from drawn copper or stainless steel tubing. Use stainless steel for units with stainless steel casings. Copper tubing shall comply with ASTM B75 and ASTM B280. Minimum tube wall thickness shall be **0.030 inch (0.8 mm)**. Include internal piping and external pressure transmitter ports.
 5. Station Labeling: Identification label on each station casing indicating model number, size, area, and application-specific airflow range.
 6. Performance:
 - a. Pressure Loss: **0.015-inch wg (3.8 Pa)** at **1000 fpm (5 m/s)**, or **0.085-inch wg (22.5 Pa)** at **2000 fpm (10 m/s)**.
 - b. Accuracy: Within 2 percent of actual airflow.
 - c. Self-Generated Sound: NC 40 and sound level within the duct shall not be amplified.
 - d. Performance rated and tested according to AMCA 610. Each station shall bear the AMCA seal.
- D. Pitot-Tube Fan Inlet Airflow Traverse Sensor:
1. Traverse manifold designed for mounting in fan inlets.
 2. Contain multiple total- and static-pressure sensors placed at concentric area centers along the exterior surface of cylindrical manifold and internally connected to their respective averaging manifolds. Sensors shall not protrude beyond the surface of the manifold nor be adversely affected by particle contamination present in airstream.
 3. Manifold (two per inlet) shall have dual end support swivel brackets suitable for mounting in the fan inlet bell and symmetrical averaging signal takeoffs and fittings.
 4. Sensors shall be capable of producing steady, non-pulsating signals of standard total- and static-pressure without need for flow corrections or factors, with an accuracy of 3 percent of actual flow over a turndown range of 6 to 1.
 5. Manifold Materials: [**Type 316 stainless steel**].

6. Unless otherwise required by application and without affecting the fan and sensor performance, nominal diameter copper and aluminum manifolds shall be the following:
 - a. For Fan Inlets Smaller Than 20 Inches (500 mm): 0.375 inch (9 mm).
 - b. For Fan Inlets 20 Inches (500 mm) and Larger: 0.75 inch (19 mm).
7. Unless otherwise required by application and without affecting the fan and sensor performance, nominal diameter stainless steel manifolds shall be the following:
 - a. For Fan Inlets Smaller Than 20 Inches (500 mm): 0.375 inch (9 mm).
 - b. For Fan Inlets 20 through 48 Inches (500 through 1200 mm): 0.75 inch (19 mm).
 - c. For Fan Inlets Larger Than 48 Inches (1200 mm): 1.0 inch (25 mm).

E. Piezometer Ring Fan Inlet Airflow Sensor:

1. In lieu of externally mounted fan inlet airflow sensors, option to provide fans with airflow measurement integral to fan inlet cones for continuous measurement of air volume flow rate.
2. Multiple pressure sensor points strategically placed along the circumference of the inlet cone and internally connected to an averaging ring manifold located behind the inlet cone.
3. Sensor points shall not protrude beyond the surface of the inlet cone nor be adversely affected by particle contamination present in the airstream.
4. Sensor shall produce steady, non-pulsating signals to achieve accuracy within 5 percent of actual airflow.
5. Sensor shall be non-intrusive and not impact fan performance.
6. Product shall be a standard offering of the fan manufacturer and include published literature with supporting test data to validate sensor performance.

2.4 AIRFLOW SWITCHES

A. Stainless Steel Single Vane Switch:

1. Description:
 - a. Velocities up to 2000 fpm (10.2 m/s).
 - b. Suitable for mounting with air direction in horizontal.
2. Performance:
 - a. Voltage: 125-, 240-, and 480-V ac.
 - b. Full Load Current: 9.8 A at 125-V ac.
 - c. Field-Adjustable Velocity Set Point: 400 to 1600 fpm (2.0 to 8.2 m/s).
 - d. Maximum Process Temperature: 180 deg F (82 deg C).
 - e. Maximum Ambient Temperature: 125 deg F (52 deg C).
3. Construction:
 - a. Stainless steel vane.
 - b. Vane actuates a SPDT snap switch.
 - c. Enclosure Material: Die-cast metal.
 - d. Enclosure with removable cover.

- e. NEMA 250, Type 1 enclosure.
- f. Screw set-point adjustment.
- g. Electrical Connections: Screw terminals.
- h. Conduit Connections: **1-inch (27-mm)** trade size conduit knock outs on top and bottom.

2.5 AIRFLOW TRANSMITTERS

A. Airflow Transmitter with 0.10 Percent Accuracy and Auto-Zero Feature:

1. Transmitter shall receive total- and static-pressure signals from a primary element, amplify signals, extract the square root, and scale the signals to produce 4- to 20-mA dc output signals linear to airflow.
2. NEMA 250, Type 1 enclosure.
3. Construct assembly so that shock, vibration, and pressures surges of up to **1 psig (6.9 kPa)** will neither harm transmitter, nor affect its accuracy.
4. Transmitter with automatic zeroing circuit capable of automatically readjusting transmitter zero at predetermined time intervals. The automatic zeroing circuit shall re-zero transmitter to within 0.1 percent of true zero.
5. Performance:
 - a. Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
 - b. Calibrated Span: Field adjustable, minus 40 percent of the range.
 - c. Accuracy: Within 0.10 percent of natural span.
 - d. Repeatability: Within 0.15 percent of calibrated span.
 - e. Linearity: Within 0.2 percent of calibrated span.
 - f. Hysteresis and Deadband (Combined): Less than 0.2 percent of calibrated span.
6. Integral digital LED or digital display for continuous indication of airflow.

B. Pressure Differential Indicating Transmitter, Switch, and Controller for Airflow Measurement:

1. Description:
 - a. Three-in-one instrument, including digital display, control relay switches, and a transmitter with a current output.
 - b. Field configurable for pressure, velocity, and volumetric flow applications through user interface.
 - c. Select instrument range based on application.
2. Performance:
 - a. Accuracy including hysteresis and repeatability:
 - 1) Ranges Less than **5-Inch wg (1250 Pa)**: Within 1 percent.
 - 2) Other Ranges: Within 0.5 percent at **77 deg F (25 deg C)**.
 - b. Stability: Within 1 percent per year.
 - c. Response Time: 250 ms.

- d. Overpressure:
 - 1) Ranges Less than 50-Inch wg (12.5 kPa): 5 psi (34.5 kPa).
 - 2) Range of 100-Inch wg (25 kPa): 9 psi (62 kPa).
 - e. Temperature Limits: 32 to 140 deg F (Zero to 60 deg C).
 - f. Thermal Effects: 0.020 percent per deg F (deg C).
 - g. Warm-up Period: One hour.
- 3. Controller: Programming through menu keys to access five menus.
 - a. Security level.
 - b. Pressure, velocity, or flow application.
 - c. Engineering units.
 - d. K-factor for use with flow application.
 - e. Set-point control only; set-point and alarm operation; alarm operation as high, low, or high/low with manual; or automatic reset and delay.
 - f. View high and low readings.
 - g. Digital dampening for smoothing erratic applications.
 - h. Scaling of analog output to fit range and field calibration.
 - 4. Display:
 - a. Four-digit digital, with minimum 0.4-inch- (10-mm-) high alphanumeric characters.
 - b. Four LED indicators; two LEDs for set point and two LEDs for alarm status.
 - 5. Operator Interface:
 - a. Set-point adjustment through keypad on face of instrument.
 - b. Zero and span adjustments accessible through menu.
 - c. Programming through keypad.
 - 6. Output Analog Signal: Two-wire, 4- to 20-mA dc current source; capable of operating into a 900-ohm load.
 - 7. Output Digital Signal: Two, SPDT relays; each rated for 1 A at 30-V ac or 30-V dc.
 - 8. Construction:
 - a. Die-cast aluminum casing and bezel.
 - b. Connections on side and back.
 - c. Vertical plane mounting.
 - d. NEMA 250, Type 1 rating.
 - e. Nominal 4-inch- (100-mm-) diameter face.
 - f. Mounting Bracket: Appropriate for installation.

2.6 LIQUID FLOW METERS

A. General Requirements for Liquid Flow Meters:

- 1. Adjustable for changes in system operational parameters.

2. Liquid and Steam Sensors, Meters, and Transmitters: Extended range of [10] percent above Project design flow and [10] percent below Project minimum flow to signal abnormal flow conditions.
3. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
4. Product certificates are required.

B. Inline Turbine Flow Meter:

1. Description:
 - a. Available in NPS 3/4 and NPS 1 (DN 20 and DN 25).
 - b. Operating pressure of 300 psig (2068 kPa) with a temperature of 200 deg F (93 deg C).
 - c. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than 250 deg F (121 deg C).
 - d. Pressure drop not to exceed 3 psig at 38 gpm (21 kPa at 2.4 L/s).
 - e. Sensor Accuracy:
 - 1) Within 2 percent of actual flow between the flow range of 0.8 to 38 gpm (0.05 to 2.4 L/s).
 - 2) Within 0.5 percent of actual reading at the calibrated velocity.
 - f. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.
2. Sensor:
 - a. Rotational sensing of turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).
 - b. Sensor shall have an integral frequency output linear with flow rate.
 - c. Sensor shall have threaded union on each end.
 - d. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts.
 - e. Construct wetted metal components of brass or stainless steel.
 - f. House sensor electronics in a NEMA 250, Type 4 enclosure.
 - g. Enclosure shall include connection(s) for field-installed conduit.
 - h. Sensor shall have cable of length sufficient to connect to display module.
3. Display Module:
 - a. Remote from sensor.
 - b. Enclosure: NEMA 250, Type 4X.
 - c. Label terminal strip for all wiring connections.
 - d. 120-V ac power supply with 24-V dc output to power the flow sensor.
 - e. Remote Interface:
 - 1) Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
 - 2) Serial Communication Interface: Compatible with host to share flow rate and totalized flow data.
 - 3) Outputs linear to within 0.1 percent of calibrated span.

- f. Digital display of flow rate and totalized flow.
- g. At least eight display digits for totalization.
- h. Local reset of flow totalization.
- i. Program and data shall be stored in nonvolatile memory in the event of power loss.

2.7 LIQUID FLOW SENSORS (PRIMARY ELEMENTS)

A. Segmented Wedge Flow Sensor:

- 1. Description: Pressure differential design using a segmented or segmental wedge installed in a straight section of pipe.
- 2. Performance: [**Product test reports are required.**]
 - a. Accuracy within 0.5 percent of the measured flow over flow range from design flow to 10 percent of design flow.
 - b. Accuracy with 10 pipe diameters of straight pipe upstream and five pipe diameters downstream.
 - c. Repeatability shall be within 0.2 percent over flow range.
 - d. Discharge coefficient shall be linear and stable throughout the flow range.
 - e. Determine H/ID ratios to meet specified performance.
 - f. Capable of bi-directional flow measurement with no degradation of performance, with flow in either direction.
 - g. Suitable for working pressure of **200 psig at 200 deg F (1379 kPa at 93 deg C)**.
- 3. Construction:
 - a. Pipe: Type 316 stainless steel with inside diameter to match adjacent pipe. Length determined by manufacturer.
 - b. Wedge: Type 316 stainless steel segmented angled wedge equal on both sides.
 - c. Flanges: Class 150 [**weld neck**] [**raised face**], Type 316 stainless steel.
 - d. Instrument Connections: **NPS 1/2 (DN 15)**, Class 3000, Type 316 stainless steel half couplings.
 - e. Identification Tag: Stamped or engraved stainless steel.
- 4. Use with a pressure differential transmitter.

2.8 LIQUID FLOW SWITCHES

A. Liquid Flow Switch (Magnetic Type):

- 1. Description:
 - a. Field-adjustable five-vane combinations.
 - b. Suitable for pipe sizes **NPS 1-1/2 through NPS 20 (DN 40 to DN 500)**.
 - c. Mounting Suitable for Application: Switch vertically mounted in horizontal pipe, or switch horizontally mounted in vertical pipe with flow up.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous-environment Class I, Groups C and D; Class II, Groups E, F, and G.

2. Performance:

- a. Flow Rate Actuation and De-actuation: Varies with vane combination.
- b. Pressure Limit: 1000 psig (6895 kPa) for brass body, 2000 psig (13790 kPa) for Type 316 stainless steel body.
- c. Temperature Range: Minus 4 to plus 275 deg F (Minus 20 to plus 135 deg C).
- d. Electrical Rating: 10 A at 125/250-V ac.
- e. Switch Type: [SPDT] [DPDT] snap switch.

3. Wetted Parts Construction:

- a. Vanes: Type 316 stainless steel.
- b. Body: [Type 316 stainless steel].
- c. Magnetic Keeper: [Type 316 stainless steel].
- d. Process Connection: NPS 1-1/2 (DN 40).

4. Enclosure:

- a. Die-cast aluminum alloy.
- b. Threaded cover.
- c. NEMA 250, Type 4.
- d. Electrical Connection: Terminal block.
- e. Conduit Connection: 3/4-inch (21-mm) trade size.

B. Liquid Flow Switch (Magnetic Type) for Small-Diameter Pipe:

1. Description:

- a. Suitable for pipe sizes NPS 1/2 through NPS 2 (DN 15 through DN 50).
- b. Mounting Suitable for Application: Switch vertically mounted in horizontal pipe, or switch horizontally mounted in vertical pipe with flow up.
- c. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous-environment Class I, Groups A, B, C, and D; Class II, Groups E, F, and G.

2. Performance:

- a. Flow Rate Actuation and De-actuation: Not adjustable.
- b. Pressure Limit of Body: 1000 psig (6895 kPa) for brass, 2000 psig (13790 kPa) for Type 303 stainless steel body.
- c. Pressure Limit of Tee: 250 psig (1724 kPa) for brass, 1000 psig (6895 kPa) for malleable iron, and 2000 psig (13790 kPa) for forged carbon steel and stainless steel.
- d. Temperature Range: Minus 4 to plus 220 deg F (Minus 20 to plus 104 deg C).
- e. Electrical Rating: 5 A at 125/250-V ac.
- f. Switch Type: [SPDT] [DPDT] snap switch.

3. Wetted Parts Construction (Lower Body):
 - a. Vanes: Type 301 stainless steel.
 - b. Body: **[Type 303 stainless steel]**.
 - c. Magnet: Ceramic.
 - d. Process Connection: **NPS 1/2 (DN 15)**.
4. Enclosure (Upper Body):
 - a. **[Type 303 stainless steel]**.
 - b. NEMA 250, Type 4.
 - c. Electrical Connection: Terminal block.
 - d. Conduit Connection: **3/4-inch (21-mm)** trade size.
5. Integral Mounting Tee Furnished with Switch:
 - a. **[Stainless steel]**.
 - b. Size: **[Match adjacent pipe]**
 - c. Connection: Threaded pipe.

2.9 LIQUID FLOW TRANSMITTERS

- A. Pressure Differential Transmitter with 0.07 Percent Accuracy for Flow Measurement **[in Hazardous Environment]**:
 1. FM Approved for hazardous environments.
 - a. Intrinsically safe for Classes I, II, and III, Divisions 1 and 2, Groups A through H.
 - b. Explosion-Proof for Class I, Division 1, Groups B, C, and D.
 - c. Dust-Ignition-Proof for Class II, Division 1, Groups E, F, and G.
 - d. Dust-Ignition-Proof for Class III, Division 1.
 2. Performance:
 - a. Range: **Minus 250- to 250-inch wg (Minus 62.5 to 62.5 kPa)**.
 - b. Span: Field adjustable.
 - c. Minimum Span: **2.5-inch wg (500 Pa)**.
 - d. Accuracy: Within 0.07 percent of span or better.
 - e. Stability: Within 0.125 percent of upper range limit for 5 years.
 - f. Overpressure Limits: **3626 psig (25000 kPa)**.
 - g. Process Temperature Limits: **Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C)**.
 - h. Ambient Temperature Limits: **Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C)**.
 - i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - j. Shock and vibration shall not harm the transmitter.

3. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Digital signal based on HART protocol carried with current signal.
 - d. Dampening: Field selectable zero to 30 seconds.
 4. Operator Interface: Zero and span adjustments located behind cover.
 5. Display: Five-digit, two-line digital display with **0.4-inch- (10-mm-)** high alphanumeric characters.
 6. Construction:
 - a. Nonwetted parts of transmitter constructed of aluminum or stainless steel.
 - b. Enclosure with removable cover on each side.
 - c. Wetted parts of transmitter constructed of Type 316 stainless steel.
 - d. **NPS 1/2 (DN 15)** process connections on bottom of instrument.
 - e. Drain/vent valve on low- and high-pressure connections.
 - f. Two **1/2-inch (16-mm)** trade size conduit connection on side of instrument enclosure.
 - g. Screw terminal block for wire connections.
 - h. NEMA 250, Type 4X.
 - i. Mounting bracket suitable for installation.
 7. Five-Valve Manifold:
 - a. Each transmitter shall have integrally mounted manifold.
 - b. Construct manifold body of Type 316 stainless steel.
 - c. Manifold shall have **NPS 1/2 (DN 15)** process connections.
- B. Liquid Pressure Differential Transmitter for Flow Measurement:
1. Performance:
 - a. Range: Approximately 2 times the set point.
 - b. Span: Adjustable plus or minus 1 mA, non-interactive.
 - c. Accuracy: Within 0.25 percent of full scale.
 - d. Maximum Operating Pressure: 2.5 times range.
 - e. Temperature Limits: **Zero to 175 deg F (Minus 18 to plus 79 deg C).**
 - f. Compensate Temperature Limits: **30 to 150 deg F (Minus 1 to plus 66 deg C).**
 - g. Thermal Effects: 0.02 percent of full scale per degree F.
 - h. Response Time: 30 to 50 ms.
 - i. Shock and vibration shall not harm the transmitter.
 2. Analog Output Current Signal:
 - a. Two wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.

3. Operator Interface:
 - a. Zero and span adjustments located behind cover.
 - b. Bleed screws on side of body, two screws on low-pressure side and one screw on high-pressure side, for air in line and pressure cavity.
4. Construction:
 - a. Aluminum and stainless steel enclosure with removable cover.
 - b. Wetted parts of transmitter constructed of 17-4 PH or 300 series stainless steel.
 - c. NPS 1/4 (DN 8) process connections on side of instrument enclosure.
 - d. Knock out for 1/2-inch (15-mm) trade size conduit connection on side of instrument enclosure.
 - e. Screw terminal block for wire connections.
 - f. NEMA 250, Type 4X.
 - g. Mounting bracket shall be suitable for installation.
5. Transmitter shall have three-valve manifold. Construct manifold of brass, bronze, or stainless steel. Manifold shall have NPS 1/4 (DN 8) process connections.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Provide the services of an independent inspection agency to confirm that proposed mounting locations comply with requirements indicated and approved submittals.
 1. Indicate dimensioned locations with mounting height for all surface-mounted products to walls and ceilings on shop drawings.
 2. Do not begin installation without submittal approval of mounting location.
- E. Complete installation rough-in only after confirmation by independent inspection is complete and approval of location is documented for review by Owner and Architect on request.
- F. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- G. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTRUMENT APPLICATIONS

- A. Select from instrument types to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.
- B. Thermal Airflow Measurement Stations:
 - 1. For Air-Ducted/Plenum:
 - a. Measured Velocities Greater Than 200 fpm (1.0 m/s): Thermal airflow measurement station.
 - b. Provide a remotely mounted microprocessor-based transmitter at each measurement location.
 - 2. For Air-Ducted/Plenum - Duct Size 2 sq. ft. (0.18 sq. m) or Less:
 - a. Measured Velocities Less Than 200 fpm (1.0 m/s): Thermal airflow measurement station.
 - b. Provide a remotely mounted microprocessor-based transmitter at each measurement location.
 - 3. For Supply or Return Fan Array:
 - a. Measured Velocities Greater Than 200 fpm (1.0 m/s): Thermal airflow measurement station.
 - b. Provide a remotely mounted microprocessor-based transmitter at each measurement location.
 - 4. For Supply or Return Fan, Single-Width Single-Inlet (SWSI) or Double-Width Double-Inlet (DWDI) Fans:
 - a. Measured Velocities Greater Than 200 fpm (1.0 m/s): Thermal airflow measurement station.
 - b. Provide a remotely mounted microprocessor-based transmitter at each measurement location.
 - 5. For Air Terminal Units:
 - a. Measured Velocities Greater Than 200 fpm (1.0 m/s): Thermal airflow measurement station.
 - b. Provide a microprocessor-based transmitter at each measurement location.
 - 6. For Packaged HVAC Units, 12.5 Tons (44.0 kW) or Smaller:
 - a. Measured Velocities Greater Than 200 fpm (1.0 m/s): Thermal airflow measurement station.
 - b. Provide a remotely mounted microprocessor-based transmitter at each measurement location.

7. For Directional Airflow Sensors:
 - a. Measured Velocities Greater Than **50 fpm (0.25 m/s)**: Thermal airflow measurement station.
 - b. Provide a remotely mounted microprocessor-based transmitter at each measurement location.
8. For Data Center Server Rack Airflow/Pressure and Temperature Monitor:
 - a. Measured Velocities Greater Than **200 fpm (1.0 m/s)**: Thermal airflow measurement station.
 - b. Provide a remotely mounted microprocessor-based transmitter at each measurement location.
9. For Damper-Mounted Airflow Stations:
 - a. Measured Velocities Greater Than **200 fpm (1.0 m/s)**: Thermal airflow measurement station.
 - b. Provide a remotely mounted microprocessor-based transmitter at each measurement location.
- C. Duct-Mounted Airflow Sensors:
 1. Measured Velocities [**500 fpm (2.5 m/s)**] and Less: Thermal airflow station.
 2. Measured Velocities Greater than [**500 fpm (2.5 m/s)**]: [**Pitot-tube airflow sensor station**]
- D. Damper-Mounted Airflow Sensors:
 1. Measured Velocities [**400 fpm (2.0 m/s)**] and Less: Thermal airflow station.
 2. Measured Velocities Greater than [**500 fpm (2.5 m/s)**]: [**Damper with integral flow measurement**].
- E. Fan-Mounted Airflow Sensors:
 1. Measured Velocities [**500 fpm (2.5 m/s)**] and Less: Thermal airflow station.
 2. Measured Velocities Greater than [**500 fpm (2.5 m/s)**] : [**Pitot-tube fan inlet airflow sensor station**].
- F. Airflow Switches:
 1. Measured Velocities **400 fpm (2.0 m/s)** and Less: Polymer film sail switch.
 2. Measured Velocities Greater than **400 fpm (2.0 m/s)**: Stainless steel single-vane switch.
- G. Airflow Transmitters for Use with Pitot-Tube-Type Sensors:
 1. Exhaust Air Airflow: [**Airflow transmitter with 0.10 percent accuracy and auto-zero feature**].
 2. Outdoor Air Airflow: [**Airflow transmitter with 0.10 percent accuracy and auto-zero feature**].

3. Return Air Airflow: [**Airflow transmitter with 0.10 percent accuracy and auto-zero feature**].
4. Supply Air Airflow: [**Airflow transmitter with 0.10 percent accuracy and auto-zero feature**].

H. Liquid Flow Switches:

1. < **cooling and heating** >: [**Magnetic type**].

I. Liquid Flow Transmitters:

1. < **cooling and heating** > : [**Pressure differential transmitter with 0.07 percent accuracy for flow measurement**].

3.3 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Properly support instruments, tubing, piping wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a force.
- D. Install ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- E. 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.
- F. Corrosive Environments:
 1. Use products that are suitable for environment to which they will be subjected.
 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 3. When conduit is in contact with a corrosive environment, use Type 316 stainless steel conduit and fittings or conduit and fittings with a corrosive-resistant coating that is suitable for environment.
 4. Where instruments are located in a corrosive environment and are not corrosive resistant from the 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 "Raceway and Boxes for Electrical Systems."

3.5 INSTRUMENTS, GENERAL INSTALLATION REQUIREMENTS

A. Mounting Location:

- 1. Rough-in: Outline instrument-mounting locations before setting instruments and routing cable, wiring, tubing, and conduit to final location.
- 2. Install switches and transmitters for air and liquid flow associated with individual air-handling units and connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
- 3. Install liquid and steam flow switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
- 4. Install airflow switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
- 5. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
- 6. Install instruments in steam, liquid, and liquid-sealed-piped services below their process connection point. Slope tubing down to instrument with a slope of [2] percent.
- 7. Install instruments in dry gas and non-condensable-vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of [2] percent.

B. Mounting Height:

- 1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
- 2. Mount switches and transmitters, located in mechanical equipment rooms and other similar space not subject to code, state, and federal accessibility requirements, within a range of 42 to 72 inches (1050 to 1800 mm) above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at 60 inches (1500 mm).

- C. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

3.6 INSTALLATION OF FLOW INSTRUMENTS

A. Airflow Sensors:

1. Install sensors in straight sections of duct with manufacturer-recommended straight duct upstream and downstream of sensor.
2. Installed sensors shall be accessible for visual inspection and service. Install access door(s) in duct or equipment located upstream of sensor, to allow service personnel to hand clean sensors.

B. Liquid and Steam Sensors:

1. Install sensors in straight sections of piping with manufacturer-recommended straight piping upstream and downstream of sensor.
2. Alert manufacturer where installation cannot accommodate recommended clearance, and solicit recommendations for field modifications to installation, such as flow straighteners, to improve condition.
3. Install pipe reducers for in-line sensors smaller than line size. Position reducers at distance from sensor to avoid interference and impact on accuracy.
4. Install in-line sensors with flanges or unions to provide drop-in and -out installation.

C. Liquid Flow Meters:

1. Install meters in straight sections of piping with manufacturer-recommended straight piping upstream and downstream of sensor.
2. Install pipe reducers for in-line meters smaller than line size. Install reducers at distance from meter to avoid interference and impact on accuracy.
3. Install in-line meters with flanges or unions to provide drop-in and -out installation.
4. Insertion Meters:
 - a. Install system process connections full size of meter connection, but not less than [NPS 1 (DN 25)] [NPS 1-1/2 (DN 40)]. Provide [stainless steel] bushing if required to mate to system connection.
 - b. Install meter in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement.
 - c. In applications where top-dead-center location is not possible due to field constraints, install meter at location along top half of pipe if acceptable by manufacturer for mounting orientation.

D. Liquid Switches:

1. Install system process connection full size of switch connection, but not less than [NPS 1 (DN 25)] [NPS 1-1/2 (DN 40)]. Install [stainless steel] bushing if required to mate switch to system connection.
2. Install switch in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement.

3. In applications where top-dead-center location is not possible due to field constraints, install switch at location along top half of pipe if switch is acceptable by manufacturer for mounting orientation.

E. Transmitters:

1. Install airflow transmitters serving an air system in a single location adjacent to or within system control panel.
2. Install liquid flow transmitters, not integral to sensors, in vicinity of sensor. Where multiple flow transmitters serving same system are located in same room, co-locate transmitters by system to provide service personnel a single and convenient location for inspection and service.

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 instrument identification [**and on face of ceiling directly below instruments concealed above ceilings**].

3.8 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.
- C. Polish glossy surfaces to a clean shine.

3.9 CHECKOUT PROCEDURES

A. Description:

1. Check out installed products before continuity tests, leak tests, and calibration.
2. Check instruments for proper location and accessibility.
3. Check instruments for proper installation with respect to direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
4. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.

B. Flow Instrument Checkout:

1. Verify that sensors are installed correctly with respect to flow direction.
2. Verify that sensor attachment is properly secured and sealed.

3. Verify that processing tubing attachment is secure and isolation valves have been provided.
4. Inspect instrument tag against approved submittal.
5. Verify that recommended upstream and downstream distances have been maintained.

3.10 ADJUSTMENT, CALIBRATION, AND TESTING

A. Description:

1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
4. Equipment and procedures used for calibration shall meet instrument manufacturer's recommendations.
5. Provide diagnostic and test equipment for calibration and adjustment.
6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If after-calibration-indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.11 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include] [12] months' full maintenance by [**manufacturer's authorized service representative**]. Include [**monthly**] preventive maintenance, repair or replacement of worn or defective components, cleaning, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.12 DEMONSTRATION

- A. [**Engage a factory-authorized service representative to train**] Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.14

SECTION 230923.23 - PRESSURE INSTRUMENTS

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. Air-pressure sensors.
2. Air-pressure switches.
3. Air-pressure transmitters.
4. Liquid-pressure switches.
5. Liquid-pressure transmitters.

- 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 230923.23.

1.3 DEFINITIONS

- A. HART: Highway addressable remote transducer protocol is the global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bi-directional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from technician's hand-held device or laptop to a control, asset management, safety, or other system using any control platform.

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. Number-coded identification system for unique identification of wiring, cable, and tubing ends.

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, pipe, and equipment.
 - 2. Wall-mounted instruments located in finished space, showing relationship to light switches, fire alarm devices, and other installed devices.
 - 3. Size and location of wall access panels for instruments installed behind walls.
 - 4. Size and location of ceiling access panels for instruments installed in accessible ceilings.
- B. Product Certificates: For each product requiring a certificate.
- C. Product Test Reports: For each product requiring test performed by [**manufacturer and witnessed by a qualified testing agency**].
- D. Source quality-control reports.
- E. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

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

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Environmental Conditions:

1. Instruments shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - a. If instrument alone cannot comply with requirement, install instrument in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated[**and cooled**], filtered, and ventilated as required by instrument and application.
2. Instruments and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Instrument-installed location shall dictate following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: [**Type 12**]
 - b. Outdoors, Unprotected: [**Type 4X**]
 - c. Indoors, Heated with Filtered Ventilation: [**Type 2**]
 - d. Indoors, Heated with Nonfiltered Ventilation: [**Type 12**]
 - e. Indoors, Heated and Air-Conditioned: [**Type 1**]
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: [**Type 12**]
 - 2) Air-Moving Equipment Rooms: [**Type 12**]
 - g. Localized Areas Exposed to Washdown: [**Type 4X**]
 - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: [**Type 12**]
 - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: [**Type 4X**].
 - j. Hazardous Locations: Explosion-proof rating for condition.

2.2 AIR-PRESSURE SENSORS

A. Duct Insertion Static Pressure Sensor:

1. Sensor probe with two opposing orifices designed to reduce error-associated air velocity.
2. Sensor insertion length shall be [**4 inches (100 mm)**] [**or**] [**8 inches (200 mm)**].
3. Construct sensor of [**Type 304 stainless steel**].
4. Connection: Threaded, **NPS 1/8 (DN 6)** swivel fitting for connection to copper tubing or **NPS 1/4 (DN 10)** barbed fitting for connection to polyethylene tubing.
5. Sensor probe attached to a mounting flange with neoprene gasket and two holes for fasteners.

6. Mounting flange shall suitable for flat oval, rectangular, and round duct configurations.
7. Pressure Rating: 10 psig (69 kPa).

B. Outdoor Static Pressure Sensor:

1. Sensor with no moving parts.
2. Operation not affected and impaired by rain and snow.
3. Sensing plates constructed of 0.1406-inch (3.6-mm) Type 316 stainless steel.
4. Accuracy within:
 - a. 1 percent of the actual outdoor atmospheric pressure when subjected to varying horizontal radial wind velocities up to 40 mph.
 - b. 2 percent of the actual outdoor atmospheric pressure while subjected to varying radial wind velocities up to 40 mph with approach angles up to 30 degrees to horizontal.
 - c. 3 percent of the actual outdoor atmospheric pressure while subjected to varying radial wind velocities up to 40 mph with approach angles up to 60 degrees to horizontal.
 - d. Threaded, NPS 2 (DN 50) connection.

C. Space Static Pressure Sensor for Wall Mounting:

1. [Stainless-steel] wall plate with perforated center arranged to sense space static pressure. Exposed surfaces are provided with brush finish.
2. Wall plate provided with screws and sized to fit standard single-gang electrical box.
3. Back of sensor plate fitted with multiple sensing ports, pressure impulse suppression chamber, airflow shielding, and 0.125-inch (3-mm) fitting for tubing connection.
4. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of 1000 fpm (5.1 m/s) from a 360-degree radial source.

D. Space Static Pressure Sensor for Recessed Ceiling Mounting:

1. [Stainless-steel] round plate with perforated center arranged to sense space static pressure. Exposed surfaces provided with brush finish.
2. Sensor intended for flush mount on face of ceiling with pressure chamber recessed in ceiling plenum.
3. Back of sensor plate fitted with multiple sensing ports, pressure impulse suppression chamber, airflow shielding, and 0.125-inch (3-mm) fitting for concealed tubing connection.
4. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of 1000 fpm (5.1 m/s) from a 360-degree radial source.

E. Space Static Pressure Sensor for Exposed or Suspended Mounting:

1. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of 1000 fpm (5.1 m/s) from a 360-degree radial source.
2. [Stainless steel] with perforations arranged to sense space static pressure. Exposed surfaces provided with brush finish.
3. Sensor fitted with multiple sensing ports, pressure impulse suppression chamber, and airflow shielding.

4. Surface-mounted sensor provided with solid mounting plate intended for mount to ceiling with pressure chamber exposed to view.
5. Surface-mounted sensor with 0.125-inch (3-mm) fitting for exposed tubing connection.
6. Suspended sensor intended for pendent mount with pressure chamber exposed to view.
7. Suspended sensor with NPS 1/2 (DN 15) fitting for exposed pipe or tubing connection.

2.3 AIR-PRESSURE SWITCHES

A. Air-Pressure Differential Switch:

1. Diaphragm operated to actuate an SPDT snap switch.
 - a. Fan safety shutdown applications: Switch with manual reset.
2. Electrical Connections: Three-screw configuration, including one screw for common operation and two screws for field-selectable normally open or closed operation.
3. Enclosure Conduit Connection: Knock out or threaded connection.
4. User Interface: Screw-type set-point adjustment located inside removable enclosure cover.
5. High and Low Process Connections: Threaded, NPS 1/8 (DN 6).
6. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - c. Hazardous Environments: Explosion proof.
7. Operating Data:
 - a. Electrical Rating: 15 A at 120- to 480-V ac.
 - b. Pressure Limits:
 - 1) Continuous: 45 inches wg (11.2 kPa).
 - 2) Surge: 10 psig (68.9 kPa).
 - c. Temperature Limits: Minus 30 to 180 deg F (Minus 34 to 82 deg C).
 - d. Operating Range: Approximately 2 times set point.
 - e. Repeatability: Within 3 percent.
 - f. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Air-Pressure Differential Switch with Dual Scale Adjustable Set Point:

1. Diaphragm operated to actuate an SPDT snap switch.
2. Electrical Connections: Push-on screw terminals.
3. Enclosure Conduit Connection: Knock out or threaded connection.
4. User Interface: Dual scale set-point adjustment knob located inside removable enclosure cover.
5. High and Low Process Connections: Slip-on tubing connections.

6. Enclosure:

- a. Dry Indoor Installations: NEMA 250, Type 13.

7. Operating Data:

- a. Electrical Rating: 1.5 A at 250-V ac.
- b. Pressure Limits: 40 inches wg (10 kPa)
- c. Temperature Limits: Minus 4 to 185 deg F (Minus 20 to 85 deg C).
- d. Operating Range: Approximately 2 times set point.

C. Air-Pressure Differential Indicating Switch:

- 1. Combination gage with low- and high-limit switches.
- 2. Nominal 4-inch- (100-mm-) diameter analog indication with white dial face, graduated black markings, pointer to indicate measured value, and a separate adjustable pointer for each switch set point.
- 3. Switch zero and set-point [tamperproof] adjustment screws or knobs on the dial face.
- 4. Each switch used as a safety limit shall have a manual reset button local to switch.
- 5. Switch Type: Each set point shall have two Form C relays, DPDT.
- 6. Electrical Connections: Screw terminals.
- 7. Enclosure Conduit Connection: NPS 3/4 (DN 20) threaded connection.
- 8. High and Low Process Connections: Threaded, NPS 1/8 (DN 6).
- 9. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - c. Hazardous Environments: Explosion proof.
- 10. Operating Data:
 - a. Electrical Rating: 10 A at 120- to 240-V ac.
 - b. Pressure Limits: 25 psig (172 kPa).
 - c. Temperature Limits: 20 to 120 deg F (Minus 7 to 49 deg C).
 - d. Operating Range: Approximately twice normal operating range unless otherwise required for application.
 - e. Accuracy:
 - 1) 4 percent for ranges through 0.5 in. wg (125 Pa).
 - 2) 2 percent for ranges 1 in. wg (250 Pa) and greater.
 - f. Repeatability: Within 1 percent of full scale.
 - g. Switch Deadband: One pointer width and within 1 percent of full scale for each switch set point.
 - h. Power Supply: [24] [or] [120]-V ac, 50/60 Hz.
 - i. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.4 AIR-PRESSURE TRANSMITTERS

A. Air-Pressure Differential Transmitter:

1. Performance:

- a. Range: Approximately 2 times set point.
- b. Accuracy: Within [1] percent of the full-scale range.
- c. Hysteresis: Within 0.10 percent of full scale.
- d. Repeatability: Within 0.05 percent of full scale.
- e. Stability: Within 1 percent of span per year.
- f. Overpressure: 10 psig (69 kPa).
- g. Temperature Limits: Zero to 150 deg F (Minus 18 to 66 deg C).
- h. Compensate Temperature Limits: 40 to 150 deg F (4 to 66 deg C).
- i. Thermal Effects: 0.033 percent of full scale per degree F.
- j. Shock and vibration shall not harm the transmitter.

2. Output Signals:

a. Analog Current Signal:

- 1) Two-wire, 4- to 20-mA dc current source.
- 2) Signal capable of operating into 800-ohm load.

b. Analog Voltage Signal:

- 1) Three wire, zero to [10] V.
- 2) Minimum Load Resistance: 1000 ohms.

3. Display: Four-digit digital display with minimum 0.4-inch- (10-mm-) high numeric characters.

4. Operator Interface: Zero and span adjustments located behind cover.

5. Construction:

- a. Plastic casing with removable plastic cover.
- b. Threaded, NPS 1/4 (DN 10) swivel fittings for connection to copper tubing or NPS 3/16 (DN 7) barbed fittings for connection to polyethylene tubing. Fittings on bottom of instrument case.
- c. Screw terminal block for wire connections.
- d. Vertical plane mounting.
- e. NEMA 250, Type 4.
- f. Provide mounting bracket suitable for installation.

B. Air-Pressure Differential Transmitters for Hazardous Environments:

1. FM Approved for hazardous environments. Intrinsically safe for Classes I, II, and III, Divisions 1 and 2, Groups A through H.

2. Performance:
 - a. Range: Approximately 2 times set point.
 - b. Accuracy: Within] [0.5] percent of the span at reference temperature of 70 degrees F.
 - c. Hysteresis: Within 0.02 percent of the span.
 - d. Repeatability: Within 0.05 percent of the calibrated span.
 - e. Stability: Within 0.25 percent of span per year.
 - f. Overpressure: 20 psig (138 kPa).
 - g. Temperature Limits: Minus 20 to 185 deg F (Minus 29 to 85 deg C).
 - h. Compensate Temperature Limits: Zero to 160 deg F (Minus 18 to 71 deg C).
 - i. Thermal Effects: 0.01 percent of full scale per degree F.
 - j. Warm-up Time: Within 5 seconds.
 - k. Response Time: [8 ms].
 - l. Shock and vibration shall not harm the transmitter.
3. Output Signals:
 - a. Analog Current Signal:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - b. Analog Voltage Signal:
 - 1) Three wire, zero to [5]V.
 - 2) Minimum Load Resistance: 1000 ohms.
4. Operator Interface:
 - a. Zero and span adjustments within 10 percent of full span.
 - b. Potentiometer adjustments located on face of transmitter.
5. Construction:
 - a. Type 300 stainless-steel enclosure.
 - b. Swivel fittings for connection to tubing. Fittings on bottom of instrument enclosure.
 - c. Two 1/2-inch (16-mm) trade size conduit connections isolated from electronics.
 - d. Screw terminal block for wire connections.
 - e. Vertical plane mounting.
 - f. NEMA 250, Type 4X.
 - g. Mounting Bracket: Appropriate for installation.
6. Reverse wiring protected.
7. Calibrate to NIST-traceable standards and provide each transmitter with a certificate of calibration.

C. Air-Pressure Differential Transmitter with 0.10 Percent Accuracy and Auto Zero Feature:

1. Description:

- a. 4- to 20-mA dc output signal.
- b. NEMA 250, Type 1 enclosure.
- c. Construct the assembly so that shock, vibration, and pressure surges of up to **1 psig (6.9 kPa)** will neither harm nor affect the accuracy of the transmitter.
- d. Transmitter with automatic zeroing circuit capable of automatically readjusting the transmitter to zero at predetermined time intervals. The automatic zeroing circuit shall re-zero the transmitter to within 0.1 percent of true zero.
- e. Performance:
 - 1) Range: Approximately 2 times set point.
 - 2) Calibrated Span: Field adjustable, minus 40 percent of the range.
 - 3) Accuracy: Within 0.10 percent of natural span.
 - 4) Repeatability: Within 0.15 percent of calibrated span.
 - 5) Linearity: Within 0.2 percent of calibrated span.
 - 6) Hysteresis and deadband (combined): Less than 0.2 percent of calibrated span.
- f. Integral digital display for continuous indication of pressure differential.

2.5 LIQUID-PRESSURE SWITCHES

A. Liquid-Pressure Differential Switch:

1. Description:

- a. Type 316 stainless-steel double opposing bellows operate to actuate an SPDT snap switch.
- b. Wetted materials: Type 316 stainless steel.
- c. Seal: **[Buna-N] [or] [Viton]**.
- d. Electrical Connections: Screw terminal.
- e. Enclosure Conduit Connection: Knock out or threaded connection.
- f. User Interface: Thumbscrew set-point adjustment with enclosed set-point indicator and scale.
- g. High and Low Process Connections: Threaded, **NPS 1/4 (DN 10)**.
- h. Enclosure: NEMA 250, Type 4 or 4X.
- i. Operating Data:
 - 1) Electrical Rating: 10 A at 120- to 240-V ac.
 - 2) Pressure Limits: **Zero to 500 psig (Zero to 3447 kPa)**.
 - 3) Ambient Temperature Limits: **Minus 20 to 150 deg F (Minus 29 to 66 deg C)**.
 - 4) Process Temperature Limits: **20 to 300 deg F (Minus 7 to 149 deg C)**.
 - 5) Operating Range: 2 times set point, unless otherwise required by application.
 - 6) Deadband: **[Adjustable or fixed as required by application]**.

- j. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.6 LIQUID-PRESSURE TRANSMITTERS

A. Liquid Gage Pressure Transmitter with Adjustable Span[**for Hazardous Environments**]:

1. Hazardous Classification: FM Approved for hazardous environments.
 - a. Intrinsically safe for Classes I, II, and III, Divisions 1 and 2, Groups A through H.
 - b. Explosion proof for Class I, Division 1, Groups B, C, and D.
 - c. Dust ignition proof for Class II, Division 1, Groups E, F, and G.
2. Performance:
 - a. Range: **Minus 300 to 300 psig (Minus 2068 to 2068 kPa)**.
 - b. Span: Field adjustable.
 - c. Minimum Span: **3 psig (21 kPa)**.
 - d. Reference Accuracy: Within 0.07 percent of span or better.
 - e. Stability: Within 0.125 percent of upper range limit for 5 years.
 - f. Overpressure Limits: **3626 psig (25 000 kPa)**.
 - g. Process Temperature Limits: **Minus 40 to 250 deg F (Minus 40 to 121 deg C)**.
 - h. Ambient Temperature Limits: **Minus 40 to 185 deg F (Minus 40 to 85 deg C)**.
 - i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - j. Shock and vibration shall not harm the transmitter.
3. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Digital signal based on HART protocol carried with current signal.
 - d. Dampening: Field selectable from zero to 30 seconds.
4. Operator Interface: Zero and span adjustments located behind cover.
5. Display: Digital, five-digit, two-line display with **0.4-inch- (10-mm-)** high alphanumeric characters.
6. Construction:
 - a. Non-wetted parts of transmitter constructed of aluminum or stainless steel.
 - b. Enclosure with removable cover on each side.
 - c. Wetted parts of transmitter constructed of Type 316 stainless steel.
 - d. Threaded, **NPS 1/2 (DN 15)** process connection on bottom of instrument.
 - e. Drain/vent valve on process connection.
 - f. Two **1/2-inch (16-mm)** trade size conduit connections on side of instrument enclosure.
 - g. Screw terminal block for wire connections.
 - h. NEMA 250, Type 4X.
 - i. Mounting Bracket: Appropriate for installation.

B. Liquid-Pressure Differential Transmitter with Adjustable Span[for **Hazardous Environments**]:

1. Hazardous Classification: FM Approved for hazardous environments.
 - a. Intrinsically safe for Classes I, II, and III, Divisions 1 and 2, Groups A through H.
 - b. Explosion proof for Class I, Division 1, Groups B, C, and D.
 - c. Dust ignition proof for Class II, Division 1, Groups E, F, and G.
2. Performance:
 - a. Range: **Minus 300 to 300 psig** (**Minus 2068 to 2068 kPa**).
 - b. Span: Field adjustable.
 - c. Minimum Span: **3 psig** (**21 kPa**).
 - d. Reference Accuracy: Within 0.07 percent of span or better.
 - e. Stability: Within 0.125 percent of upper range limit for 5 years.
 - f. Overpressure Limits: **3626 psig** (**25 000 kPa**).
 - g. Process Temperature Limits: **Minus 40 to 250 deg F** (**Minus 40 to 121 deg C**).
 - h. Ambient Temperature Limits: **Minus 40 to 185 deg F** (**Minus 40 to 85 deg C**).
 - i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - j. Shock and vibration shall not harm the transmitter.
3. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Digital signal based on HART protocol carried with current signal.
 - d. Dampening: Field selectable from zero to 30 seconds.
4. Operator Interface: Zero and span adjustments located behind cover.
5. Display: Digital, five-digit, two-line display with **0.4-inch-** (**10-mm-**) high alphanumeric characters.
6. Construction:
 - a. Non-wetted parts of transmitter constructed of aluminum or stainless steel.
 - b. Enclosure with removable cover on each side.
 - c. Wetted parts of transmitter constructed of Type 316 stainless steel.
 - d. Threaded, **NPS 1/2 (DN 15)** process connection on bottom of instrument.
 - e. Drain/vent valve on process connection.
 - f. Two **1/2-inch** (**16-mm**) trade size conduit connections on side of instrument enclosure.
 - g. Screw terminal block for wire connections.
 - h. NEMA 250, Type 4X.
 - i. Mounting Bracket: Appropriate for installation.

C. Liquid-Pressure Differential Transmitter with Field-Selectable Range:

1. Performance:
 - a. Field-Selectable Range:
 - 1) 5, 10, 25, 50 psig (34, 69, 172, 345 kPa).
 - b. Field-selectable unidirectional or bidirectional range.
 - c. Accuracy: Within 1 percent of the full-scale range, except lowest selectable range within 2 percent.
 - d. Stability: Within 0.5 percent of span per year.
 - e. Pressure: Maximum operating pressure equal to highest pressure in range.
 - f. Overpressure: Proof pressure 2.2 times full scale; burst pressure 40 times full scale.
 - g. Temperature Limits: Minus 44 to 185 deg F (Minus 42 to 85 deg C).
 - h. Compensate Temperature Limits: 32 to 130 deg F (Zero to 54 deg C).
 - i. Thermal Effects: 2 percent of full scale per 100 deg F (56 deg C).
 - j. Response Time: Field selectable from 1 to 5 seconds.
 - k. Shock and vibration shall not harm the transmitter.
2. Configurable Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
3. Configurable Analog Output Voltage Signals:
 - a. Three wire, zero to 5 V, zero to 10 V, and 1 to 5 V.
 - b. Minimum Load Resistance: 1000 ohms.
4. Display: Four-digit LCD with minimum 0.4-inch- (10-mm-)high numeric characters.
5. Operator Interface:
 - a. Digital zero button located behind cover.
 - b. Range selector located behind cover.
6. Construction:
 - a. Cast-aluminum enclosure with removable cover.
 - b. Wetted parts of transmitter constructed of 17-4 PH stainless steel.
 - c. Threaded, NPS 1/8 (DN 6) process connections on bottom of instrument enclosure.
 - d. 1/2-inch (16-mm) trade size connection for conduit on bottom of instrument enclosure.
 - e. Screw terminal block for wire connections.
 - f. Vertical plane mounting.
 - g. NEMA 250, Type 4.
 - h. Mounting Bracket: Appropriate for installation.

2.7 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect assembled pressure instruments, as indicated by instrument requirements. Affix standards organization's certification and label.
- B. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PRESSURE INSTRUMENT APPLICATIONS

- A. Duct-Mounted Static Pressure Sensors:
 - 1. **<as per drawings> [Duct insertion static pressure sensor]**
- B. Space Static Pressure Sensors:
 - 1. **<as per drawings>: [Space static pressure sensor for wall mounting] [Space static pressure sensor for recessed ceiling mounting] [Space static pressure sensor for exposed or suspended mounting].**
- C. Air-Pressure Differential Switches:
 - 1. **<as per drawings>: [Air-pressure differential switch] [Air-pressure differential switch with set-point indicator].**
- D. Air-Pressure Differential Transmitters:
 - 1. Duct, **<as per drawings>: [Air-pressure differential transmitter] [Air-pressure differential transmitter for hazardous environments] [Air-pressure differential indicating transmitter] [Air-pressure differential transmitter with 0.10 percent accuracy and auto zero feature] .**
 - 2. Space, **<as per drawings>: [Air-pressure differential transmitter] [Air-pressure differential transmitter for hazardous environments] [Air-pressure differential**

indicating transmitter] [Air-pressure differential transmitter with 0.10 percent accuracy and auto zero feature] [.

E. Liquid Gage Pressure Switches:

1. **<as per drawings>: [Liquid gage pressure switch, diaphragm operated] [Liquid gage pressure switch, bourdon-tube operated].**

F. Liquid-Pressure Differential Switches:

1. **<as per drawings> [Liquid-pressure differential switch with set-point indicator] [Liquid-pressure differential switch].**

G. Liquid-Pressure Differential Transmitters:

1. **<as per drawings>: [Liquid-pressure differential transmitter] [Liquid-pressure differential transmitter with field-selectable range].**

3.3 INSTALLATION, GENERAL

A. Install products level, plumb, parallel, and perpendicular with building construction.

B. Properly support instruments, tubing, piping wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement, sway, or a break in attachment when subjected to a force.

C. Provide ceiling, floor, roof, 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. Fastening Hardware:

1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by using excessive force or oversized wrenches.
3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.

E. Install products in locations that are accessible and that 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.

F. Corrosive Environments:

1. Use products that are suitable for environment to which they are subjected.
2. If possible, avoid or limit use of materials in corrosive environments.
3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.

4. Where instruments are located in a corrosive environment and are not corrosive resistant from the manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRICAL 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 PRESSURE INSTRUMENT INSTALLATION

- A. Mounting Location:
 1. Rough-in: Outline instrument-mounting locations before setting instruments and routing, cable, wiring, tubing, and conduit to final location.
 2. Install switches and transmitters for air and liquid pressure associated with individual air-handling units and associated connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
 3. Install liquid and steam pressure switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 4. Install air-pressure switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 5. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
 6. Install instruments (except pressure gages) in steam, liquid, and liquid-sealed piped services below their process connection point. Slope tubing down to instrument with a slope of [2] percent.
 7. Install instruments in dry gas and noncondensable vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of [2] percent.
- B. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

C. Duct Pressure Sensors:

1. Install sensors using manufacturer's recommended upstream and downstream distances.
2. Unless indicated on Drawings, locate sensors approximately [50] percent of distance of longest hydraulic run. Location of sensors shall be submitted and approved before installation.
3. Install mounting hardware and gaskets to make sensor installation airtight.
4. Route tubing from the sensor to transmitter.
5. Use compression fittings at terminations.
6. Install sensor in accordance with manufacturer's instructions.
7. Support sensor to withstand maximum air velocity, turbulence, and vibration encountered to prevent instrument failure.

D. Outdoor Pressure Sensors:

1. Install roof-mounted sensor in least-noticeable location and as far away from exterior walls as possible.
2. Locate wall-mounted sensor in an inconspicuous location.
3. Submit sensor location for approval before installation.
4. Verify signal from sensor is stable and consistent to all connected transmitters. Modify installation to achieve proper signal.
5. Route outdoor signal pipe full size of sensor connection to transmitters. Install branch connection of size required to match to transmitter.
6. Install sensor signal pipe with dirt leg and drain valve below roof penetration.
7. Insulate signal pipe with flexible elastomeric insulation as required to prevent condensation.
8. Connect roof-mounted signal pipe exposed to outdoors to building grounding system.

E. Air-Pressure Differential Switches:

1. Install air-pressure sensor in system for each switch connection. Install sensor in an accessible location for inspection and replacement.
2. A single sensor may be used to share a common signal to multiple pressure instruments.
3. Install access door in duct and equipment to access sensors that cannot be inspected and replaced from outside.
4. Route **NPS 3/8 (DN 12)** tubing from sensor to switch connection.
5. Do not mount switches on rotating equipment.
6. Install switches in a location free from vibration, heat, moisture, or adverse effects, which could damage the switch and hinder accurate operation.
7. Install switches in an easily accessible location serviceable from floor.
8. Install switches adjacent to system control panel if within [**50 feet (15 m)**]; otherwise, locate switch in vicinity of system connection.

F. Liquid-Pressure Differential Switches:

1. Where process connections are located in mechanical equipment room, install switch in convenient and accessible location near system control panel.
2. Where process connections are installed outside mechanical rooms, route processing tubing to mechanical room housing system control panel and locate switch near system control panel.

3. Where multiple switches serving same system are installed in same room, install switches by system to provide service personnel a single and convenient location for inspection and service.
4. System process tubing connection shall be full size of switch connection, but not less than **[NPS 1/2 (DN 15)]**. Install **[stainless-steel]** bushing if required to mate switch to system connection.
5. Connect process tubing from point of system connection and extend to switch.
6. Install isolation valves in process tubing as close to system connection as practical.
7. Install dirt leg and drain valve at each switch connection.
8. Do not mount switches on rotating equipment.
9. Install switches in a location free from vibration, heat, moisture, or adverse effects, which could damage the switch and hinder accurate operation.
10. Install switches in an easily accessible location serviceable from floor.

G. Liquid-Pressure Transmitters:

1. Where process connections are installed in mechanical equipment room, install transmitter in convenient and accessible location near system control panel.
2. Where process connections are installed outside mechanical rooms, route processing tubing to mechanical room housing system control panel and locate transmitter near system control panel.
3. Where multiple transmitters serving same system are installed in same room, install transmitters by system to provide service personnel a single and convenient location for inspection and service.
4. System process tubing connection shall be full size of switch connection, but not less than **[NPS 1/2 (DN 15)]**. Install **[stainless-steel]** bushing if required to mate switch to system connection.
5. Connect process tubing from point of system connection and extend to transmitter.
6. Install isolation valves in process tubing as close to system connection as practical.
7. Install dirt leg and drain valve at each transmitter connection.
8. Do not mount transmitters on equipment.
9. Install in a location free from vibration, heat, moisture, or adverse effects, which could damage and hinder accurate operation.

3.6 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 instrument identification **[and on face of ceiling directly below instruments concealed above ceilings]**.

3.7 CHECKOUT PROCEDURES

- A. Check out installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.

- C. Check instruments for proper installation with respect to direction of flow, elevation, orientation, insertion depth, or other applicable considerations that impact performance.

3.8 ADJUSTMENT, CALIBRATION, AND TESTING

A. Description:

1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
3. For each analog instrument, perform a three-point calibration test for both linearity and accuracy.
4. Equipment and procedures used for calibration shall comply with instrument manufacturer's recommendations.
5. Provide diagnostic and test equipment for calibration and adjustment.
6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If, after calibration, indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of project design values.

3.9 ADJUSTING

- A. Occupancy Adjustments: When requested within [12] months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [two] visits to Project during other-than-normal occupancy hours for this purpose.

3.10 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include [12] months' full maintenance by [manufacturer's authorized service representative]. Include [monthly] preventive maintenance, repair or replacement of worn or defective components, cleaning, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.11 DEMONSTRATION

- A. [Engage a factory-authorized service representative to train] Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate pressure instrument demonstration video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.23

SECTION 230923.27 - TEMPERATURE INSTRUMENTS

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. Air temperature sensors.
2. Air temperature switches.
3. Air temperature RTD transmitters.
4. Liquid and steam temperature sensors.
5. Liquid temperature switches.

- 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 230923.27.

1.3 DEFINITIONS

- A. HART (Highway Addressable Remote Transducer) Protocol: The global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bidirectional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from a technician's hand-held device or laptop to a plant's process control, asset management, safety, or other system using any control platform.

- B. RTD: Resistance temperature detector.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.

2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation operation and maintenance instructions, including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and[**mounting**] details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

C. Samples: For each exposed product installed in finished space.

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, pipe, and equipment.
2. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices, and other installed devices.
3. Sizes and locations of wall access panels for instruments installed behind walls.
4. Sizes and locations of ceiling access panels for instruments installed in inaccessible ceilings.

B. Product Certificates: For each product requiring a certificate.

C. Product Test Reports: For each product, for tests performed by [**manufacturer and witnessed by a qualified testing agency**].

D. Field quality-control reports.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Provide [**two**] matching product(s) in Project inventory for each unique size and type.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Environmental Conditions:

1. Instruments shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - a. If instrument alone cannot meet requirement, install instrument in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated[**and cooled**], filtered, and ventilated as required by instrument and application.
2. Instruments and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Instrument's installed location shall dictate following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: [**Type 12**]
 - b. Outdoors, Unprotected: [**Type 4X**].
 - c. Indoors, Heated with Filtered Ventilation: [**Type 2**]
 - d. Indoors, Heated with Non-Filtered Ventilation: [**Type 12**] .
 - e. Indoors, Heated and Air Conditioned: [**Type 1**] .
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: [**Type 12**]
 - 2) Air-Moving Equipment Rooms: [**Type 12**]
 - g. Localized Areas Exposed to Washdown: [**Type 4X**]
 - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: [**Type 12**]
 - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: [**Type 4X**]
 - j. Hazardous Locations: Explosion-proof rating for condition.

2.2 AIR TEMPERATURE SENSORS

A. Platinum RTDs: Common Requirements:

1. 100 or 1000 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
2. Two-wire, PTFE-insulated, 22-gage stranded copper leads.
3. Performance Characteristics:
 - a. Range: **Minus 50 to 275 deg F** (**Minus 46 to 135 deg C**).
 - b. Interchangeable Accuracy: At **32 deg F** (**zero deg C**) within **0.5 deg F** (**0.3 deg C**).

- c. Repeatability: Within 0.5 deg F (0.3 deg C).
 - d. Self-Heating: Negligible.
- 4. Transmitter Requirements:
 - a. Transmitter required for each 100-ohm RTD.
 - b. Transmitter optional for 1000-ohm RTD, contingent on compliance with end-to-end control accuracy.
- B. Platinum RTD, Single-Point Air Temperature Duct Sensors:
 - 1. [100] [or] [1000] ohms.
 - 2. Temperature Range: Minus 50 to 275 deg F (Minus 45 to 135 deg C).
 - 3. Probe: Single-point sensor with a stainless-steel sheath.
 - 4. Length: As required by application to achieve tip at midpoint of air tunnel, up to 18 inches (450 mm) long).
 - 5. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
 - 6. Gasket for attachment to duct or equipment to seal penetration airtight.
 - 7. Conduit Connection: 1/2-inch (16-mm) trade size.)
- C. Platinum RTD, Air Temperature Averaging Sensors:
 - 1. [100] [or] [1000] ohms.
 - 2. Temperature Range: Minus 50 to 275 deg F (Minus 45 to 135 deg C).
 - 3. Multiple sensors to provide average temperature across entire length of sensor.
 - 4. Rigid probe of aluminum, brass, copper, or stainless-steel sheath.
 - 5. Flexible probe of aluminum, brass, copper, or stainless-steel sheath and formable to a 4-inch (100-mm) radius.
 - 6. Length: As required by application to cover entire cross section of air tunnel.
 - 7. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
 - 8. Gasket for attachment to duct or equipment to seal penetration airtight.
 - 9. Conduit Connection: 1/2-inch (16-mm) trade size.)
- D. Platinum RTD Outdoor Air Temperature Sensors:
 - 1. [100] [or] [1000] ohms.
 - 2. Temperature Range: Minus 50 to 275 deg F (Minus 45 to 135 deg C).
 - 3. Probe: Single-point sensor with a stainless-steel sheath.
 - 4. Solar Shield: Stainless steel.
 - 5. Enclosure: NEMA 250, Type 4 or 4X junction box or combination conduit and outlet box with removable cover and gasket.
 - 6. Conduit Connection: 1/2-inch (16-mm) trade size.
- E. Platinum RTD Space Air Temperature Sensors:
 - 1. [100] [or] [1000] ohms.
 - 2. Temperature Range: Minus 50 to 212 deg F (Minus 45 to 100 deg C).
 - 3. Sensor assembly shall include a temperature sensing element mounted under a [flush, brushed-aluminum] cover.

4. Provide a mounting plate that is compatible with the surface shape that it is mounted to and electrical box used.
 5. Concealed wiring connection.
- F. Space Air Temperature Sensors for Use with DDC Controllers Controlling Terminal Units:
1. [100-] [or] [1000-]ohm platinum RTD[or thermistor].
 2. Thermistor:
 - a. Pre-aged, burned in, and coated with glass; inserted in a metal sleeve; and entire unit encased in epoxy.
 - b. Thermistor drift shall be less than plus or minus 0.5 deg F (0.3 deg C) over 10 years.
 3. Temperature Transmitter Requirements:
 - a. Mating transmitter required with each 100-ohm RTD.
 - b. Mating transmitters optional for 1000-ohm RTD and thermistor, contingent on compliance with end-to-end control accuracy.
 4. Provide digital display of sensed temperature.
 5. Provide sensor with local control.
 - a. Local override to turn HVAC on.
 - b. Local adjustment of temperature set point.
 - c. Both features shall be capable of manual override through control system operator.

2.3 AIR TEMPERATURE SWITCHES

- A. Thermostat and Switch for Low Temperature Control in Duct Applications:
1. Description:
 - a. Two-position control.
 - b. Field-adjustable set point.
 - c. Manual reset.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Performance:
 - a. Operating Temperature Range: 15 to 55 deg F (Minus 9 to 13 deg C).
 - b. Temperature Differential: 5 deg F (2.8 deg C), non-adjustable and additive.
 - c. Enclosure Ambient Temperature: Minus 20 to 140 deg F (Minus 11 to 60 deg C).
 - d. Sensing Element Maximum Temperature: 250 deg F (121 deg C).
 - e. Voltage: 120-V ac.
 - f. Current: 16 FLA.
 - g. Switch Type: Two SPDT snap switches operate on coldest 12-inch (300-mm)section along element length.

3. Construction:

- a. Vapor-Filled Sensing Element: Nominal 20 feet (6 m) long.
- b. Dual Temperature Scale: Fahrenheit and Celsius visible on face.
- c. Set-Point Adjustment: Screw.
- d. Enclosure: Painted metal, NEMA 250, Type 1.
- e. Electrical Connections: Screw terminals.
- f. Conduit Connection: 1/2-inch (16-mm) trade size.

B. Thermostat and Switch for High Temperature Control in Duct Applications:

- 1. Source Limitations: Obtain temperature-measuring sensors and transmitters and airflow from single manufacturer.
- 2. Description:
 - a. Two-position control.
 - b. Field-adjustable set point.
 - c. Manual reset.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- 3. Performance:
 - a. Temperature Range: 100 to 160 deg F (38 to 71 deg C).
 - b. Temperature Differential: 5 deg F (2.8 deg C).
 - c. Ambient Temperature: Zero to 260 deg F (Minus 18 to 127 deg C).
 - d. Voltage: 120-V ac.
 - e. Current: 16 FLA.
 - f. Switch Type: SPDT snap switch.
- 4. Construction:
 - a. Sensing Element: Helical bimetal.
 - b. Enclosure: Metal, NEMA 250, Type 1.
 - c. Electrical Connections: Screw terminals.
 - d. Conduit Connection: 1/2-inch (16-mm) trade size.

2.4 AIR TEMPERATURE RTD TRANSMITTERS

- A. Source Limitations: Obtain temperature-measuring sensors and transmitters and airflow from single manufacturer.
- B. House electronics in NEMA 250 enclosure.
 - 1. Duct: [Type 3].
 - 2. Outdoor: [Type 4X].
 - 3. Space: Type 1.
- C. Conduit Connection: 1/2-inch (16-mm) trade size.)

D. Functional Characteristics:

1. Input:
 - a. 100-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C, two-wire sensors.
 - b. 1000-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C, two-wire sensors.
2. Span (Adjustable):
 - a. Space: 40 to 90 deg F (4 to 32 deg C).
 - b. Supply Air Cooling and Heating: 40 to 120 deg F (4 to 49 deg C).
 - c. Supply Air Cooling Only: 40 to 90 deg F (4 to 32 deg C).
 - d. Supply Air Heating Only: 40 to 120 deg F (4 to 49 deg C).
 - e. Exhaust Air: 50 to 100 deg F (10 to 38 deg C).
 - f. Return Air: 50 to 100 deg F (10 to 38 deg C).
 - g. Mixed Air: Minus 40 to 140 deg F (Minus 40 to 60 deg C).
 - h. Outdoor: Minus 40 to 140 deg F (Minus 40 to 60 deg C).
3. Output: 4- to 20-mA dc, linear with temperature; RFI insensitive; minimum drive load of 600 ohms at 24-V dc .
4. Zero and span field adjustments, plus or minus 5 percent of span. Minimum span of 50 deg F (28 deg C).
5. Match sensor with temperature transmitter and factory calibrate together.

E. Performance Characteristics:

1. Calibration Accuracy: Within 0.1 percent of the span.
2. Stability: Within 0.2 percent of the span for at least 6 months.
3. Combined Accuracy: Within 0.5 percent.

2.5 LIQUID TEMPERATURE SWITCHES

A. Thermostat and Switch for Temperature Control in Pipe Applications:

1. Description:
 - a. Two-position control.
 - b. Field-adjustable set point.
 - c. Manual reset.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Performance:
 - a. Operating Temperature Range: 65 to 200 deg F (18 to 3 deg C).
 - b. Temperature Differential Deadband: 5 to 30 deg F (3 to 17 deg C), adjustable.
 - c. Enclosure Ambient Temperature: 150 deg F (66 deg C).
 - d. Sensing Element Pressure Rating: 200 psig (1379 kPa).

- e. Voltage: 120-V ac.
 - f. Current: 8 FLA.
 - g. Switch Type: SPDT snap switch.
3. Construction:
- a. Vapor-Filled Immersion Element: Copper, nominal **3 inches (75 mm)** long.
 - b. Temperature Scale: Fahrenheit, visible on face.
 - c. Set-Point Adjustment: Screw.
 - d. Enclosure: Painted metal, NEMA 250, Type 1.
 - e. Electrical Connections: Screw terminals.
 - f. Conduit Connection: **3/4-inch (21-mm) trade size**.

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 instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 TEMPERATURE INSTRUMENT APPLICATIONS

- A. Air Temperature Sensors:
 - 1. Duct, **<as per drawings>**: [100-ohm platinum RTD] [1000-ohm platinum RTD].
 - 2. Outdoor, **<as per drawings>**: [100-ohm platinum RTD] [1000-ohm platinum RTD].
 - 3. Space, **<as per drawings>**: [100-ohm platinum RTD] [1000-ohm platinum RTD].
- B. Air Temperature Transmitters:
 - 1. Duct, **<as per drawings>**: [Air temperature RTD transmitter].
 - 2. Outdoor, **<as per drawings>**: [Air temperature RTD transmitter].
 - 3. Space, **<as per drawings>**: [Air temperature RTD transmitter].

3.3 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.

- B. Properly support instruments, tubing, piping, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a force.
- C. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of 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.
- D. Install products in locations that are accessible and that 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.
- E. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments.
 - 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 4. Where instruments 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 TEMPERATURE INSTRUMENT INSTALLATIONS

- A. Mounting Location:
 - 1. Roughing In:
 - a. Outline instrument mounting locations before setting instruments and routing cable, wiring, tubing, and conduit to final location.
 - b. Provide independent inspection to confirm that proposed mounting locations comply with requirements indicated and approved submittals.

- 1) Indicate dimensioned locations with mounting height for all surface-mounted products on Shop Drawings.
 - 2) Do not begin installation without submittal approval of mounting location.
 - c. Complete installation rough-in only after confirmation by independent inspection is complete and approval of location is documented for review by Owner and Architect on request.
 2. Install switches and transmitters for air and liquid temperature associated with individual air-handling units and associated connected ductwork and piping near air-handling units co-located in air-handling unit system control panel to provide service personnel a single and convenient location for inspection and service.
 3. Install liquid and steam temperature switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 4. Install air temperature switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 5. Mount switches and transmitters on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer's mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
- B. Special Mounting Requirements:
1. Protect products installed outdoors from solar radiation, building and wind effect with stand-offs and shields constructed of **[Type 316 stainless]**
 2. Temperature instruments having performance impacted by temperature of mounting substrate shall be isolated with an insulating barrier located between instrument and substrate to eliminate effect. Where instruments requiring insulation are located in finished space, conceal insulating barrier in a cover matching the instrument cover.
- C. Mounting Height:
1. Mount temperature instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
 2. Mount switches and transmitters located in mechanical equipment rooms and other similar space not subject to code or state and Federal accessibility requirements within a range of **42 to 72 inches (1.1 to 1.6 m)** above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at **60 inches (1500 mm)**.
- D. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.
- E. Space Temperature Sensor Installation:
1. Conceal assembly in an electrical box of sufficient size to house sensor and transmitter, if provided.

2. Install electrical box with a faceplate to match sensor cover if sensor cover does not completely cover electrical box.
3. In finished areas, recess electrical box within wall.
4. In unfinished areas, electrical box may be surface mounted if electrical light switches are surface mounted. Use a cast-aluminum electric box for surface-mounted installations.
5. Align electrical box with other electrical devices such as visual alarms and light switches located in the vicinity to provide a neat and well-thought-out arrangement. Where possible, align in both horizontal and vertical axis.

F. Outdoor Air Temperature Sensor Installation:

1. Mount sensor in a discrete location facing north.
2. Protect installed sensor from solar radiation and other influences that could impact performance.
3. If required to have a transmitter, mount transmitter remote from sensor in an accessible and serviceable location indoors.

G. Single-Point Duct Temperature Sensor Installation:

1. Install single-point-type, duct-mounted, supply- and return-air temperature sensors. Install sensors in ducts with sensitive portion of the element installed in center of duct cross section and located to sense near average temperature. Do not exceed 24 inches (610 mm) in sensor length.
2. Install return-air sensor in location that senses return-air temperature without influence from outdoor or mixed air.
3. Rigidly support sensor to duct and seal penetration airtight.
4. If required to have transmitter, mount transmitter remote from sensor at accessible and serviceable location.

H. Averaging Duct Temperature Sensor Installation:

1. Install averaging-type air temperature sensor for temperature sensors located within air-handling units, similar equipment, and large ducts with air tunnel cross-sectional area of 20 sq. ft. (1.86 sq. m) and larger.
2. Install sensor length to maintain coverage over entire cross-sectional area. Install multiple sensors where required to maintain the minimum coverage.
3. Fasten and support sensor with manufacturer-furnished clips to keep sensor taut throughout entire length.
4. If required to have transmitter, mount transmitter in an accessible and serviceable location.

I. Low-Limit Air Temperature Switch Installation:

1. Install multiple low-limit switches to maintain coverage over entire cross-sectional area of air tunnel.
2. Fasten and support sensing element with manufacturer-furnished clips to keep element taut throughout entire length.
3. Mount switches outside of airstream at a location and mounting height to provide easy access for switch set-point adjustment and manual reset.
4. Install on entering side of cooling coil unless otherwise indicated on Drawings.

J. Liquid Temperature Sensor Installation:

1. Assembly shall include sensor, thermowell[**and connection head**].
2. For pipe **NPS 4 (DN 100)** and larger, install sensor and thermowell length to extend into pipe between 50 to 75 percent of pipe cross section.
3. For pipe smaller than **NPS 4 (DN 100)**:
 - a. Install reducers to increase pipe size to **NPS 4 (DN 100)** at point of thermowell installation.
 - b. For pipe sizes **NPS 2-1/2 and NPS 3 (DN 65 and DN 80)**, thermowell and sensor may be installed at pipe elbow or tee to achieve manufacturer-recommended immersion depth in lieu of increasing pipe size.
 - c. Minimum insertion depth shall be **2-1/2 inches (65 mm)**.
4. Install matching thermowell.
5. Fill thermowell with heat-transfer fluid before inserting sensor.
6. Tip of spring-loaded sensors shall contact inside of thermowell.
7. For insulated piping, install thermowells with extension neck to extend beyond face of insulation.
8. Install thermowell in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement. If top dead center location is not possible due to field constraints, install thermowell at location along top half of pipe.
9. For applications with transmitters, mount transmitter remote from sensor in an accessible and serviceable location from floor[**service platform or catwalk**].

3.6 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 instrument identification[**and on face of ceiling directly below instruments concealed above ceilings**].

3.7 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.
- C. Polish glossy surfaces to a clean shine.

3.8 CHECK-OUT PROCEDURES

- A. Check installed products before continuity tests, leak tests, and calibration.
- B. Check temperature instruments for proper location and accessibility.

- C. Verify sensing element type and proper material.
- D. Verify location and length.
- E. Verify that wiring is correct and secure.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING

A. Description:

1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
4. Equipment and procedures used for calibration shall meet instrument manufacturer's written instructions.
5. Provide diagnostic and test equipment for calibration and adjustment.
6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistance source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.10 FIELD QUALITY CONTROL

- A. Testing Agency: **[Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.
- C. Perform the following tests and inspections[**with the assistance of a factory-authorized service representative**]:
 1. Perform according to manufacturer's written instruction.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Prepare test and inspection reports.

3.11 ADJUSTING

- A. Occupancy Adjustments: When requested within **[12]** months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to **[two]** visits to Project during other-than-normal occupancy hours for this purpose.

3.12 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include **[12]** months' full maintenance by **[manufacturer's authorized service representative]**. Include **[monthly]** preventive maintenance, repair or replacement of worn or defective components, cleaning and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.13 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train]** Owner's maintenance personnel to adjust, operate, and maintain temperature instruments.
- B. Provide a complete set of instructional videos covering each product specified and installed and showing the following:
 1. Software programming.
 2. Calibration and test procedures.
 3. Operation and maintenance requirements and procedures.
 4. Troubleshooting procedures.

- C. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- D. Record videos on DVD disks.
- E. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.27

SECTION 230993.11 - SEQUENCE OF OPERATIONS FOR HVAC DDCGENERAL

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 control sequences for DDC for HVAC systems, subsystems, and equipment.
- B. Related Requirements:
 - 1. Section 230923 "DDC Systems for HVAC" for control equipment.

1.3 DEFINITIONS

- A. Analog Output: Proportional output signal (zero- to 10-V dc, 4 to 20 mA).
- B. Binary Output: On/off output signal or contact closure.
- C. DDC: Direct digital control.
- D. Digital Output: Data output that must be interpreted digitally.

1.4 ACTION SUBMITTALS

- A. Product Data:
 - 1. An instrumentation list for each controlled system. Label each element of the controlled system in table format. Show, in the table element name, type of device, manufacturer, model number, and control device product data sheet number.
 - 2. A complete description of the operation of the control system, including sequences of operation. Include and reference a schematic diagram of the controlled system.
- B. Shop Drawings:
 - 1. Riser diagrams showing control network layout, communication protocol, and wire types.
 - 2. Schematic diagram of each controlled system. Include all control points labeled with point names shown or listed. Show the location of control elements in the system.
 - 3. Wiring diagram for each controlled system. Show all control elements labels. Where a control element is the same as that shown on the control system schematic, label with the same name. Label all terminals.

1.5 CENTRAL CHILLED-WATER SYSTEM SEQUENCES

A. Central Chilled-Water System Time Schedule:

1. Occupied Time Schedule:

a. Input:

- 1) Device: DDC controller.
- 2) Location: Time schedule.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: DDC controller.

c. Action:

- 1) Enable startup, initiation, and control.
- 2) Energize condenser-water pumps on occupied/unoccupied cycle.
- 3) Energize condenser-water pumps on day/night cycle.
- 4) After chilled-water system shutdown, operate pump(s) for an additional [**3 minutes**]

2. Display:

a. Time and time schedule.

B. Start and Stop Condenser-Water Pump(s):

1. Enable:

a. Input:

- 1) Device: [**Level**] [**Liquid pressure**] switch.
- 2) Location: [**Cooling tower sump**] [**Pump suction**].

b. Output:

- 1) Device: Hard wired.
- 2) Location: Motor controller.
- 3) Transference: Motor-controller relay.

c. Action: Confirm adequate water level [**in cooling-tower sump**] [**at pump suction**] and energize pump(s).

2. Enable:

a. Input:

- 1) Device: [**Level transmitter**] [**or**] [**liquid pressure transmitter**].
- 2) Location: [**Cooling tower sump**] [**Pump suction**].

- 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Binary output.
 - 2) Location: Motor controller.
 - 3) Transference: Motor-controller relay.
 - c. Action: Confirm adequate water level [**in cooling-tower sump**] [**at pump suction**] and energize pump(s).
3. Enable:
- a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Software demand.
 - 3) Transference: Binary output.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Confirm cooling demand from ventilation system(s) and energize pump(s).
4. Display:
- a. Low-level cooling-tower sump alarm.
 - b. Outdoor-air temperature.
 - c. Cooling (software) demand indication.
 - d. Time and time schedule.
 - e. Condenser-water pump(s) on-off status (enabled or disabled).
 - f. Condenser-water pump(s) on-off indication (operating or not operating).
- C. Start and Stop Chilled-Water Pump(s):
1. Input:
 - a. Device: [**Flow**] [**Pressure differential**] switch.
 - b. Location: Chilled-water piping.
 - c. Transference: [**Control voltage relay**] [**DDC controller**].
 2. Output:
 - a. Device: [**Hard wired**] [**Binary output**].
 - b. Location: Motor controller.
 - c. Transference: Starter relay.
 3. Action: Energize pump(s) when the condenser-water pump(s) and system start.

4. Display:
 - a. Chilled-water flow indication.
 - b. Chilled-water pump(s) on-off status (enabled or disabled).
 - c. Chilled-water pump(s) on-off indication (operating or not operating).

D. Start and Stop Cooling-Tower Fan(s):

1. Input:
 - a. Device: **[Flow]** **[Pressure differential]** switch.
 - b. Location: Condenser-water piping.
 - c. Transference: **[Control relay]** **[DDC controller]**.
2. Output:
 - a. Device: **[Hard wired]** **[Binary output]**.
 - b. Location: Motor controller.
 - c. Transference: Starter relay.
3. Action: Energize fan(s) when the condenser-water pump(s) and system start.
4. Display:
 - a. Condenser-water flow indication.
 - b. Cooling-tower fan(s) on-off indication (operating or not operating).

E. Start and Stop Chiller(s):

1. Input:
 - a. Device: Flow switches.
 - b. Location: Condenser-water and chilled-water circuit.
 - c. Transference: **[Chiller terminal strip]** **[DDC system]**.
2. Output:
 - a. Device: **[Hard wired]** **[Binary output]**.
 - b. Location: Chiller control panel.
 - c. Transference: Chiller controls.
3. Action: Energize chiller internal control circuit when the condenser-water and chilled-water pump(s), and system start.
4. Display:
 - a. Condenser-water flow indication.
 - b. Chilled-water flow indication.
 - c. Chiller(s) on-off status (enabled or disabled).
 - d. Chiller(s) on-off indication (operating or not operating).
 - e. Chilled-water supply and return temperature.
 - f. Chilled-water temperature control-point adjustment.

F. Alternate Chiller(s):

1. Input:
 - a. Device: DDC controller.
 - b. Location: DDC software.
 - c. Transference: DDC software.
2. Output Device:
 - a. Device: DDC controller command to chiller.
 - b. Location: Chiller control panel.
 - c. Transference: Chiller controls.
3. Action:
 - a. Operate chiller(s) on lead-lag, [**alternating each startup**] [**based on adjustable runtime hour set point**].
 - b. Start additional chiller when load exceeds capacity of operating chillers as follows:
 - 1) When common chilled-water supply temperature exceeds set point for a [**30-minute**] period.
 - 2) When chiller power draw has reached its operator adjustable high limit for a [**30-minute**] period.
 - 3) When combination of outdoor temperature and time schedule ensure enough run-time before time schedule shutdown.
 - c. Stop chiller when load capacity of operating chillers drops to less than [**110**] percent of capacity of next chiller to be shut down for a [**30-minute**] period.
4. Action:
5. Display: Chiller(s) on-off indication (operating or not operating).

G. Alarm Chiller(s) Start Failure:

1. Input:
 - a. Device: [**Software signal**] [**Hardwired**].
 - b. Location: Chiller control panel.
 - c. Transference: DDC controller.
2. Output:
 - a. Device: DDC controller.
 - b. Transference: Operator's workstation.
3. Action: Signal alarm on signal from chiller control panel.
4. Display:
 - a. Chiller "failure-to-start" indication.

H. Start and Stop Chiller(s):

1. Input:
 - a. Device: Chiller control panel.
 - b. Location: Chiller.
 - c. Transference: DDC controller.
2. Output:
 - a. Device: DDC controller.
 - b. Transference: Operator's workstation.
3. Action: Report chiller electronic control, operating, and alarm functions.
4. Display:
 - a. <See chiller Sections for listing>.

I. Chilled-Water Level:

1. Input:
 - a. Device: **[Level switch] [Liquid level sensor]**.
 - b. Location: Expansion tank.
 - c. Transference: DDC controller.
2. Output:
 - a. Device: DDC controller.
 - b. Transference: Operator's workstation.
3. Action: Signal alarm on **[expansion tank low level] [low pressure]**.
4. Display: **[Expansion tank low-level] [Low-pressure]** alarm.

J. Chilled-Water Supply Temperature:

1. Input:
 - a. Device: **[Liquid temperature sensor] [or] [liquid temperature sensor with liquid temperature transmitter]**.
 - b. Location: **[Common]** chilled-water supply piping.
 - c. Transference: DDC controller.
2. Output:
 - a. Device: DDC controller signal.
 - b. Location: Local panel.
 - c. Transference: Chiller control panel.

3. Action: Maintain chilled-water supply temperature.
 - a. Reset chilled-water supply temperature based on constant return chilled-water temperature of [**54 deg F (12 deg C)**] <Insert temperature>.
4. Display:
 - a. Chilled-water supply temperature.
 - b. Chilled-water supply temperature set point.

K. Condenser-Water Temperature:

1. Input:
 - a. Device: [**Liquid temperature sensor**] [**Liquid temperature sensor with liquid temperature transmitter**].
 - b. Location: [**Cooling-tower sump**] [**Common condenser-water supply piping**].
 - c. Transference: DDC controller.
2. Output:
 - a. Device: Analog output.
 - b. Location: DDC controller.
 - c. Transference: Control-valve actuator.
3. Action: Modulate control valve open to cooling tower and closed to bypass to maintain when condenser-water supply temperature is above [**85 deg F (29 deg C)**] temperature set point. Modulate control valve closed to cooling tower and open to bypass when condenser-water supply temperature is below [**55 deg F (13 deg C)**] temperature set point.
 - a. [**85 deg F (29 deg C)**] condenser water when outdoor-air temperature is [**80 deg F (26 deg C)**] .
 - b. [**55 deg F (13 deg C)**] condenser water when outdoor-air temperature is [**55 deg F (13 deg C)**] .
4. Output:
 - a. Device: DDC controller digital output.
 - b. Location: DDC controller.
 - c. Transference: Fan variable-speed controller.
5. Action: Cycle tower fan(s) on and modulate fan speed from minimum to maximum to maintain [**55 deg F (13 deg C)**] temperature set point.
6. Action: Cycle tower fan(s) on and off to maintain condenser-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:
 - a. [**85 deg F (29 deg C)**] condenser water when outdoor-air temperature is [**80 deg F (26 deg C)**] .
 - b. [**55 deg F (13 deg C)**] condenser water when outdoor-air temperature is [**55 deg F (13 deg C)**] .

7. Display:
 - a. Control-valve(s) position.
 - b. Cooling-tower fan(s) on-off indication (operating or not operating).
 - c. Cooling-tower fan(s) speed.
 - d. Condenser-water supply temperature.
 - e. Condenser-water supply temperature set point.
 - f. Condenser-water return temperature.

L. Control Circulating Pump(s) Speed:

1. Input Device:
 - a. Device: **[Liquid pressure differential transmitter] [Liquid flow meter] [Liquid flow sensor]**.
 - b. Location: Chilled-water supply and return piping[**and condenser-water supply and return piping**] to chiller.
 - c. Transference: DDC controller.
2. Output Device:
 - a. Device: DDC controller.
 - b. Location: Motor controller.
 - c. Transference: Pump variable-speed controller.
3. Action:
 - a. Control pump speed to maintain flow through chiller.
 - b. Report pressure drop and flow.

M. Circulation through Chiller:

1. Input Device:
 - a. Device: **[Liquid pressure differential transmitter] [Liquid flow meter] [Liquid flow sensor]**.
 - b. Location: Chilled-water supply and return piping[**and condenser-water supply and return piping**] to chiller.
 - c. Transference: DDC controller.
2. Output Device:
 - a. Device: DDC controller.
3. Action:
 - a. Report pressure drop and flow through chiller.

N. Indicate the following on the operator's workstation display terminal:

1. DDC system graphic.
2. DDC system status, on-off.

3. Low-level cooling-tower sump alarm.
4. Outdoor temperature.
5. Cooling (software) demand indication.
6. Time and time schedule.
7. Condenser-water pump(s) on-off status (enabled or disabled).
8. Condenser-water pump(s) on-off indication (operating or not operating).
9. Condenser-water flow indication.
10. Chilled-water pump(s) on-off status (enabled or disabled).
11. Chilled-water pump(s) on-off indication (operating or not operating).
12. Cooling-tower fan(s) on-off indication (operating or not operating).
13. Chilled-water flow indication.
14. Refrigeration machine on-off indication (operating or not operating).
15. Chilled-water supply temperature.
16. Chilled-water return temperature.
17. Chilled-water temperature control-point adjustment.
18. Chiller(s) on-off status (enabled or disabled).
19. Chiller(s) on-off indication (operating or not operating).
20. Chiller "failure-to-start" indication.
21. Expansion tank low-level alarm.
22. Condenser-water sump (return) control-point temperature.
23. Condenser-water sump (return) temperature.
24. Condenser-water control-valve position.
25. Cooling-tower fan(s) on-off indication (operating or not operating).
26. Condenser-water supply temperature.
27. Cooling-tower sump temperature.
28. Cooling-tower sump heater on-off indication (operating or not operating).
29. Cooling-tower sump drain indication.
30. Chiller(s) power input (instantaneous).
31. Chilled-water pressure drop through chiller.
32. Chilled-water flow through chiller.
33. Condenser-water pressure drop through chiller.
34. Condenser-water flow through chiller.
35. Chiller condenser-water supply and return temperature.
36. Chiller chilled-water supply and return temperature.
37. System capacity in tons.

1.6 AIR-HANDLING-UNIT CONTROL SEQUENCES

A. Air-Handling Unit Time Schedule:

1. Occupied Time Schedule:
 - a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Time schedule.
 - 3) Transference: DDC controller.

b. Output:

- 1) Device: DDC controller.

c. Action:

- 1) Enable startup, initiation, and control.
- 2) Energize unit on occupied/unoccupied cycle.
- 3) Energize unit on day/night cycle.
- 4) Energize unit on duty cycle.
- 5) Energize return-air fans [**30 seconds**] after supply fans are energized.
- 6) Do not enable mixed-air control during morning warm-up period.
 - a) Unoccupied: Position outdoor-air [**and relief-air**] dampers closed and return-air dampers open.
- 7) Do not enable humidifier control during morning warm-up period.
- 8) Enable control of heating coil(s) during morning warm-up period.
- 9) Energize coil circulating pump(s).
- 10) Return heating control valves to normal position when unit is cycled on.
- 11) Do not enable cooling-coil control during morning warm-up period.

B. Start and Stop Supply Fan(s):

1. Enable:

a. Input:

- 1) Device: Low limit temperature switch with [manual] [automatic] reset.
- 2) Location: [Supply airstream].
- 3) Transference: Starter relay.

b. Output:

- 1) Device: Hard wired to motor controller [**and DDC controller**].
- 2) Location: Motor controller.
- 3) Input Transference: Starter relay.

c. Action:

- 1) Allow start if temperature is below [**120 deg F (49 deg C)**].
- 2) Signal alarm if fan fails to start as commanded.

2. Enable:

a. Input:

- 1) Device: Smoke detector with auxiliary contact [manual] [automatic] reset.
- 2) Location: Duct mounted [before] [and] [after] [supply fan] [air-handling unit].
- 3) Location: Mounted in air-handling unit.
- 4) Transference: Starter relay.

- b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
- c. Output Device: Hard wired through motor controller; DDC controller alarm.
- d. Action:
 - 1) Allow start if airstream is free of products of combustion.
 - 2) Signal alarm if fan fails to start as commanded.

C. Supply Fan(s) Variable-Volume Control:

1. Fan Speed Control:

- a. Input:
 - 1) Device: Air pressure transmitter.
 - 2) Location: Supply-duct static pressure referenced to ambient-space static pressure.
 - 3) Transference: DDC controller.
- b. Output:
 - 1) Device: Analog output.
 - 2) Transference: Variable-frequency motor controller.
- c. Action:
 - 1) Maintain constant supply-duct static-pressure set point.
 - 2) Set-Point Reset (for Systems with DDC of Individual Zone Terminals): Reset static-pressure set point based on the zone requiring the most pressure; reset set point lower until one zone damper is nearly wide open.
 - 3) Set variable-frequency drive to minimum speed when fan is stopped.

2. Fan Airflow:

- a. Input:
 - 1) Device: Airflow [sensor] [transmitter].
 - 2) Location: Supply duct.
 - 3) Transference: DDC controller.
- b. Output:
 - 1) Device: DDC controller.
- c. Action: Report supply-duct airflow.

3. High Pressure:

a. Input:

- 1) Device: Air pressure switch.
- 2) Location: Supply duct referenced to outside the duct.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Binary output; DDC controller.
- 2) Transference: Starter relay; operator's workstation.

c. Action: When static pressure rises above excessive-static-pressure set point of:

- 1) Stop fan.
- 2) Signal alarm.

D. Mixed-Air Control:

1. Minimum Position:

a. Input:

- 1) Device: DDC controller.
- 2) Location: Time schedule.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Outdoor damper.
- 3) Transference: Damper actuator(s).

c. Action:

- 1) Open [**minimum outdoor-air dampers**] [**outdoor-air dampers to minimum position**].

2. Carbon Dioxide Reset:

a. Input:

- 1) Device: Carbon dioxide transmitter.
- 2) Location: Space.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Dampers.
- 3) Transference: Damper actuator(s).

- c. Action: Reset minimum outdoor-air damper position to maintain carbon dioxide set point.
- 3. **[Supply] [Mixed]-Air Temperature:**
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
 - 2) Location: **[Supply-airstream] [Mixed-air plenum]**.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Damper section.
 - 3) Transference: Damper actuator(s).
 - c. Action:
 - 1) Modulate outdoor-, return-, and relief-air dampers to maintain air-temperature set point of **[55 deg F (13 deg C)]**.
 - 2) Do not enable control during morning warm-up period.
- 4. **Cooling Reset:**
 - a. Input:
 - 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] [and moisture sensors and transmitters]**.
 - 2) Location: Outdoor- and return-air ducts.
 - 3) Input Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Outdoor- and return-air ducts.
 - 3) Transference: Damper actuator(s).
 - c. Action: Set outdoor-air dampers to minimum position when outdoor-air **[temperature exceeds return-air temperature] [enthalpy exceeds return-air enthalpy]**.
- E. **Filters:**
 - 1. **Differential Pressure:**
 - a. Input:
 - 1) Device: Pressure differential **[switch] [transmitter]**.
 - 2) Location: Filter bank.
 - 3) Transference: DDC controller.

b. Output:

- 1) Device: DDC controller.
- 2) Location: DDC controller.
- 3) Transference: Operator's workstation.

c. Action: Signal alarm on **[low- and] high-pressure** conditions.

F. Hydronic Cooling Coil:

1. **[Supply] [Discharge]-Air Temperature:**

a. Input:

- 1) Device: **[Air-temperature sensor] [or] [transmitter]**.
- 2) Location: **[Supply] [Discharge]-air [duct]**.
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Cooling-coil valve.
- 3) Input Transference: Valve actuator.

c. Action:

- 1) Maintain supply-air-temperature set point of **[55 deg F (13 deg C)]** **<Insert temperature>** by modulating cooling-coil control valve.
- 2) Maintain supply-air-temperature set point within limits in response to space temperature reset:
 - a) Minimum **[55 deg F (13 deg C)]** **<Insert temperature>**.
 - b) Maximum **[68 deg F (20 deg C)]** **<Insert temperature>**.
- 3) Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

2. Temperature Reset:

a. Input:

- 1) Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.
- 2) Location: Return-air **[duct]** .
- 3) Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Cooling-coil control valve.
- 3) Transference: Valve actuator.

- c. Action: Reset supply-air temperature in straight-line relationship for the following conditions:
 - 1) [65 deg F (18 deg C)] when return-air temperature is [70 deg F (21 deg C)] .
 - 2) [55 deg F (13 deg C)] when return-air temperature is [75 deg F (24 deg C)] .
 - d. Action:
 - 1) Reset supply-air temperature in response to greatest cooling demand.
 - 2) Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.
- G. Multizone Damper Control:
- 1. Spaces Temperature:
 - a. Input Device:
 - 1) Device: [Air-temperature sensors] [or] [air-temperature sensor with air-temperature RTD transmitter].
 - 2) Location: Spaces served by system.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Multizone head.
 - 3) Transference: Damper actuators.
 - c. Action: Maintain the following space temperature set points:
 - 1) Occupied Cooling Temperature: [75 deg F (24 deg C)] .
 - 2) Occupied Heating Temperature: [70 deg F (24 deg C)] .
 - 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)] .
 - 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)] .
- H. Coordination of Air-Handling Unit Sequences: Ensure that preheat, mixed-air, heating-coil, and cooling-coil controls have common inputs and do not overlap in function.
- I. Indicate the following on the operator's workstation display terminal:
- 1. DDC system graphic.
 - 2. DDC system on-off indication (operating or not operating).
 - 3. DDC system occupied/unoccupied mode.
 - 4. Outdoor-air-temperature indication.
 - 5. Supply-fan on-off indication (operating or not operating).
 - 6. Supply duct static-pressure indication.
 - 7. Supply duct static-pressure set point.

8. Supply-fan airflow rate.
9. Supply-fan speed.
10. Return-fan on-off indication (operating or not operating).
11. Space static-pressure indication.
12. Space static-pressure set point.
13. Return-fan airflow rate.
14. Return-fan speed.
15. Mixed-air-temperature indication.
16. Mixed-air-temperature set point.
17. Mixed-air damper position.
18. Relative humidity indication.
19. Relative humidity set point.
20. Relative humidity control-valve position.
21. Filter air-pressure-drop indication.
22. Filter low-air-pressure drop set point.
23. Filter high-air-pressure drop set point.
24. **[Supply] [Discharge]**-air-temperature indication.
25. **[Supply] [Discharge]**-air-temperature set point.
26. Cooling-coil leaving-air-temperature indication.
27. Cooling-coil leaving-air-temperature set point.
28. Cooling-coil control-valve position.
29. Cold-deck air-temperature indication.
30. Cold-deck air-temperature set point.
31. Space temperature indication.
32. Space temperature set point.
33. Multizone damper position.

1.7 TERMINAL UNIT OPERATING SEQUENCE

A. Two-Pipe, Single-Coil, Fan-Coil Unit:

1. Manual Start:
 - a. Input:
 - 1) Device: Fan switch.
 - 2) Location: Integral to thermostat.
 - b. Output:
 - 1) Device: Hard wired.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Start and stop fan.

2. Space Temperature:
 - a. Input:
 - 1) Device: Electronic thermostat.
 - 2) Location: Space.
 - b. Output:
 - 1) Device: Low-voltage wiring.
 - 2) Location: Control valve.
 - 3) Transference: Valve.
 - c. Action: Modulate valve to maintain the following space temperature set points:
 - 1) Occupied Cooling Temperature: [75 deg F (24 deg C)]
 - 2) Occupied Heating Temperature: [70 deg F (24 deg C)]
 - 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)]
 - 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)]
3. Occupied Time Schedule:
 - a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Time schedule.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Binary output.
 - 2) Location: Motor controller.
 - 3) Transference: Starter relay.
 - c. Action: Start and stop fan.
4. Space Temperature:
 - a. Input:
 - 1) Device: Air-temperature sensor.
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.

- c. Action: Modulate valve to maintain the following space temperature set points:
 - 1) Occupied: [**75 deg F (24 deg C)**]
 - 2) Unoccupied: [**65 deg F (18 deg C)**]
 - d. System Changeover:
 - e. Input:
 - 1) Device: Liquid temperature sensor [or] [**liquid temperature sensor with liquid transmitter**].
 - 2) Location: Supply-water piping.
 - 3) Transference: DDC controller.
 - f. Output:
 - 1) Device: Binary output.
 - 2) Location: Control valve.
 - 3) Transference: Valve actuator.
 - g. Action: Reverse control-valve action to switch from heating to cooling.
- B. Unit Ventilator:
- 1. Occupied Time Schedule:
 - a. Input:
 - 1) Device: DDC controller.
 - 2) Location: Time schedule.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Binary output.
 - 2) Location: Fan motor controller and damper.
 - 3) Transference: Starter relay and damper actuators.
 - c. Action: Start and stop fan, move outdoor- and return-air dampers to [**minimum**] [**maximum**] outdoor-air position, and enable control.
 - 2. Space Temperature - Valves:
 - a. Input:
 - 1) Device: [**Air-temperature sensor**] [or] [**transmitter**].
 - 2) Location: Space.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve.

- 3) Transference: Valve actuator.
- c. Action: Modulate heating-water control valve and chilled-water control valve in sequence to maintain the following space temperature set points:
 - 1) Occupied Cooling Temperature: [75 deg F (24 deg C)]
 - 2) Occupied Heating Temperature: [70 deg F (24 deg C)]
 - 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)]
 - 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)]
3. Space Temperature - Dampers:
 - a. Input:
 - 1) Device: [Air-temperature sensor] [or] [air-temperature RTD transmitter].
 - 2) Location: Mixed-air plenum.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Dampers.
 - 3) Transference: Damper actuators.
 - c. Action: Modulate outdoor- and return-air dampers to maintain the following space temperature set points:
 - 1) Occupied Cooling Temperature: [75 deg F (24 deg C)]
 - 2) Occupied Heating Temperature: [70 deg F (24 deg C)]
 - 3) Unoccupied Cooling Temperature: [85 deg F (24 deg C)]
 - 4) Unoccupied Heating Temperature: [65 deg F (18 deg C)]
4. Supply-Air-Temperature Limit:
 - a. Input:
 - 1) Device: [Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter].
 - 2) Location: Discharge air.
 - 3) Transference: DDC controller.
 - b. Output:
 - 1) Device: Analog output.
 - 2) Location: Control valve and dampers.
 - 3) Transference: Valve and damper actuators.
 - c. Action: Override space temperature set point to control valves and dampers to prevent discharge air from dropping below a minimum set point.

5. Warm-up Cycle:

a. Input:

- 1) Device: DDC controller.
- 2) Location: Time schedule.
- 3) Input Transference: DDC controller.

b. Output:

- 1) Device: Analog output.
- 2) Location: Control valve and damper.
- 3) Transference: Valve and damper actuators.

c. Action: Open heating-water control valve, close outdoor-air damper, and open return-air damper.

C. Indicate the following on the operator's workstation display terminal:

1. DDC system graphic.
2. DDC system on-off indication (operating or not operating).
3. DDC system occupied/unoccupied mode.
4. Outdoor-air-temperature indication.

5. Two-Pipe, Single-Coil, Fan-Coil Unit:

- a. Space temperature indication.
- b. Space temperature set point.
- c. Control-valve position.
- d. Supply-water temperature indication.

6. Unit Ventilator:

- a. DDC system on-off indication (operating or not operating).
- b. Space temperature indication.
- c. Space temperature set point.
- d. Control-valve position.
- e. Damper position.

7. Constant-Volume, Terminal Air Units, Hydronic:

- a. Space/area served.
- b. Space occupied/unoccupied.
- c. Space temperature indication.
- d. Space temperature set point, occupied.
- e. Space temperature set point, unoccupied.
- f. Control-valve position as percentage open.

8. Sequence Control:

- a. Space/area served.
- b. Space occupied/unoccupied.
- c. Space temperature indication.
- d. Space temperature set point, occupied.
- e. Space temperature set point, unoccupied.
- f. Damper position as percentage open.
- g. Control-valve positions as percentage open.

1.8 VENTILATION SEQUENCES

A. Exhaust Fan: [**Occupancy sensor**] [**Light switch**] [**Room thermostat**].

1. Input:

- a. Device: [**Occupancy sensor**] [**Light switch**] [**Electric thermostat**].
- b. Location: Space.

2. Output:

- a. Device: Hard wired.
- b. Location: Motor controller.
- c. Transference: Starter relay.

3. Action: Cycle fan on when [**space is occupied**] [**lights are turned on**] [**space temperature rises above set point**].

B. Kitchen Exhaust Fan: Occupancy sensor.

1. Input:

- a. Device: Occupancy sensor.
- b. Location: Space.

2. Output:

- a. Device: Hard wired.
- b. Location: Motor controller.
- c. Transference: Starter relay.

3. Action: Start fan and energize makeup air unit when space is occupied.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230993.11

SECTION 232113 - HYDRONIC 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. Steel pipe and fittings.
 - 2. Joining materials.
 - 3. Transition fittings.
 - 4. Dielectric fittings.
 - 5. Bypass chemical feeder.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of the following:
 - 1. Pipe and tube.
 - 2. Fittings.
 - 3. Joining materials.
 - 4. Transition fittings.
 - 5. Bypass chemical feeder.
- B. Sustainable Design Submittals:
- C. Delegated-Design Submittal:
 - 1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion joints and loops, and attachments of the same to the building structure.
 - 2. Locations of pipe anchors and alignment guides and expansion joints and loops.
 - 3. Locations of and details for penetrations, including sleeves and sleeve seals for exterior walls, floors, basement, and foundation walls.
 - 4. Locations of and details for penetration and fire stopping for fire- and smoke-rated wall and floor and ceiling assemblies.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Piping layout, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.
- B. Qualification Data: For Installer.
- C. Welding certificates.
- D. Field quality-control reports.
- E. Preconstruction Test Reports:
 - 1. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications:
 - 1. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.
- B. Steel Support Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- C. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.
 - 1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
 - 2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

1.6 PRECONSTRUCTION TESTING

- A. Preconstruction Testing Service: [**Engage**] a qualified testing agency to perform preconstruction testing on water quality.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:
 - 1. Dual-Temperature Heating and Cooling Water Piping: [**100 psig (1034 kPa)**] at [**180 deg F (82 deg C)**].
 - 2. Makeup-Water Piping: [**150 psig (1034 kPa)**] at [**73 deg F (22 deg C)**] [**150 deg F (66 deg C)**].
 - 3. Air-Vent Piping: [**180 deg F (82 deg C)**].
 - 4. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.2 STEEL PIPE AND FITTINGS

- A. Steel Pipe: ASTM A53/A53M, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" Article.
- B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" Article.
- C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" Article.
- D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.
- E. Wrought-Steel Fittings: ASTM A234/A234M, wall thickness to match adjoining pipe.
- F. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - 1. Material Group: 1.1.
 - 2. End Connections: Butt welding.
 - 3. Facings: Raised face.
- G. Grooved Mechanical-Joint Fittings and Couplings:
 - 1. Joint Fittings: ASTM A536, Grade 65-45-12 ductile iron; ASTM A47/A47M, Grade 32510 malleable iron; ASTM A53/A53M, Type F, E, or S, Grade B fabricated steel; or ASTM A106/A106M, Grade B steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

2. Couplings: Ductile- or malleable-iron housing and [EPDM] gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

H. Plain-End Mechanical-Joint Couplings:

1. Housing: ASTM A536 Grade 65-45-12 segmented ductile iron or type 304 stainless steel.
2. Housing coating: [None]
3. Gasket: [EPDM].
4. Sealing Mechanism: Double-lip sealing system or carbon steel case-hardened jaws.
5. Bolts, hex nuts, washers, or lock bars based on manufacturer's design.
6. Minimum Pressure Rating: Equal to that of the joined pipes.

- I. Steel Pipe Nipples: ASTM A733, made of same materials and wall thicknesses as pipe in which they are installed.

2.3 JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.
- B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
- C. 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.

2.4 DIELECTRIC FITTINGS

- A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.
- B. Dielectric Unions:
1. Description:
 - a. Standard: ASSE 1079.
 - b. Pressure Rating: [125 psig (860 kPa) minimum at 180 deg F (82 deg C)].
 - c. End Connections: Solder-joint copper alloy and threaded ferrous.
- C. Dielectric Flanges: 1. Description:
- a. Standard: ASSE 1079.
 - b. Factory-fabricated, bolted, companion-flange assembly.
 - c. Pressure Rating: [125 psig (860 kPa) minimum at 180 deg F (82 deg C)] [300 psig (2070 kPa)].
 - d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solderjoint copper alloy and threaded ferrous.

D. Dielectric-Flange Insulating Kits:

1. Description:
 - a. Nonconducting materials for field assembly of companion flanges.
 - b. Pressure Rating: [**150 psig (1035 kPa)**].
 - c. Gasket: Neoprene or phenolic.
 - d. Bolt Sleeves: Phenolic or polyethylene.
 - e. Washers: Phenolic with steel backing washers.

E. Dielectric Nipples: 1. Description:

- a. Standard: IAPMO PS 66.
- b. Electroplated steel nipple, complying with ASTM F1545.
- c. Pressure Rating: [**300 psig (2070 kPa) at 225 deg F (107 deg C)**].
- d. End Connections: Male threaded or grooved.
- e. Lining: Inert and noncorrosive, propylene.

2.5 BYPASS CHEMICAL FEEDER

A. Description: Welded steel construction; **125-psig (860-kPa)** working pressure; **5-gal. (19-L)** capacity; with fill funnel and inlet, outlet, and drain valves.

1. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

- A. Chilled-water and cooling tower piping, aboveground, [**NPS 2 (DN 50) and smaller**], shall be the following:
 1. [**Schedule 40**] carbon steel pipe; [**Class 150, malleable-iron**] fittings; cast-iron flanges and flange fittings; and threaded joints.
- B. Chilled-water and cooling tower piping, aboveground, [**NPS 2-1/2 (DN 65) and larger**], shall be the following:
 1. [**Schedule 40**] carbon steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
- C. Makeup-water piping installed aboveground shall be the following:
 1. [**Schedule 40**] galvanized pipe and fittings, and threaded joints.
- D. Condensate-Drain Piping, PVC: Schedule 40 PVC plastic pipe and fittings and solvent-welded joints.

E. Air-Vent Piping:

1. Inlet: Same as service where installed according to piping manufacturer's written instructions.

3.2 EARTHWORK

- A. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.

3.3 INSTALLATION OF PIPING

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- E. Install piping to permit valve servicing.
- F. Install piping at indicated slopes.
- G. Install piping free of sags and bends.
- H. Install fittings for changes in direction and branch connections.
- I. Install piping to allow application of insulation.
- J. Select system components with pressure rating equal to or greater than system operating pressure.
- K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.
- L. Install drains, consisting of a tee fitting, NPS 3/4 (DN 20) ball valve, and short NPS 3/4 (DN 20) threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.
- M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

- N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.
- O. Install branch connections to mains using [**mechanically formed**] tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.
- P. Install valves according to the following:
 - 1. Section 230523.11 "Globe Valves for HVAC Piping."
 - 2. Section 230523.12 "Ball Valves for HVAC Piping."
 - 3. Section 230523.13 "Butterfly Valves for HVAC Piping."
 - 4. Section 230523.14 "Check Valves for HVAC Piping."
 - 5. Section 230523.15 "Gate Valves for HVAC Piping."
- Q. Install unions in piping, [**NPS 2 (DN 50)**] and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.
- R. Install flanges in piping, [**NPS 2-1/2 (DN 65)**] and larger, at final connections of equipment and elsewhere as indicated.
- S. Install shutoff valve immediately upstream of each dielectric fitting.
- T. Comply with requirements in Section 230516 "Expansion Fittings and Loops for HVAC Piping" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.
- U. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for identifying piping.
- V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."

3.4 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. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.

2. **Damaged Threads:** Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- D. **Welded Joints:** Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.
- E. **Flanged Joints:** Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.
- F. **Plastic Piping Solvent-Cemented Joints:** Clean and dry joining surfaces. Join pipe and fittings according to the following:
 1. Comply with ASTM F402 for safe-handling practice of cleaners, primers, and solvent cements.
 2. **PVC Pressure Piping:** Join ASTM D1785 schedule number, PVC pipe and PVC socket fittings according to ASTM D2672. Join other-than-schedule number PVC pipe and socket fittings according to ASTM D2855.
- G. **Grooved Joints:** Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid, grooved-end-pipe couplings.
- H. **Plain-End Mechanical-Coupled Joints:** Prepare, assemble, and test joints in accordance with manufacturer's written installation instructions.

3.5 INSTALLATION OF DIELECTRIC FITTINGS

- A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.
- B. Dielectric Fittings for [**NPS 2 (DN 50)**] and Smaller: Use dielectric [**unions**].
- C. Dielectric Fittings for [**NPS 2-1/2 to NPS 4 (DN 65 to DN 100)**]: Use dielectric [**flanges**].
- D. Dielectric Fittings for [**NPS 5 (DN 125)**] and Larger: Use dielectric flange kits.

3.6 INSTALLATION OF HANGERS AND SUPPORTS

- A. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hangers, supports, and anchor devices.
- C. Install hangers for [**copper tubing**] [**and**] [**steel piping**], with maximum horizontal spacing and minimum rod diameters, to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

- D. Install hangers for plastic piping, with maximum horizontal spacing and minimum rod diameters, to comply with manufacturer's written instructions, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.
- E. Install hangers for fiberglass piping, with maximum horizontal spacing and minimum rod diameters, to comply with manufacturer's written instructions, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.
- F. Support horizontal piping within [**12 inches (300 mm)**] of each fitting and coupling.
- G. Support vertical runs of [**copper tubing**] [**and**] [**steel piping**] to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.
- H. Support vertical runs of [**PVC**] piping to comply with manufacturer's written instructions, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.
- I. Support vertical runs of fiberglass piping to comply with manufacturer's written instructions, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

3.7 TERMINAL EQUIPMENT CONNECTIONS

- A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.
- B. Install control valves in accessible locations close to connected equipment.
- C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.
- D. Install ports for pressure gauges and thermometers at coil inlet and outlet connections. Comply with requirements in Section 230519 "Meters and Gages for HVAC Piping."

3.8 CHEMICAL TREATMENT

- A. Perform an analysis of makeup water to determine type and quantities of chemical treatment needed to keep system free of scale, corrosion, and fouling, and to sustain the following water characteristics:
 - 1. pH: [**9.0 to 10.5**]
 - 2. "P" Alkalinity: [**100 to 500**] ppm.
 - 3. Boron: [**100 to 200**] ppm.
 - 4. Chemical Oxygen Demand: Maximum of [**100**] ppm. Revise this value if closed system contains glycol.

5. Corrosion Inhibitor:
 - a. Sodium Nitrate: [1000 to 1500] ppm.
 - b. Molybdate: [200 to 300] ppm.
 - c. Chromate: [200 to 300] ppm.
 - d. Sodium Nitrate Plus Molybdate: [100 to 200] ppm each.
 - e. Chromate Plus Molybdate: [50 to 100] ppm each.
6. Soluble Copper: Maximum of [0.20] ppm.
7. Tolyriazole Copper and Yellow Metal Corrosion Inhibitor: Minimum of [10] ppm.
8. Total Suspended Solids: Maximum of [10] ppm.
9. Ammonia: Maximum of [20] ppm.
10. Free Caustic Alkalinity: Maximum of [20] ppm.
11. Microbiological Limits:
 - a. Total Aerobic Plate Count: Maximum of [1000] organisms/mL.
 - b. Total Anaerobic Plate Count: Maximum of [100] organisms/mL.
 - c. Nitrate Reducers: [100] organisms/mL.
 - d. Sulfate Reducers: Maximum of [zero] organisms/mL.
 - e. Iron Bacteria: Maximum of [zero] organisms/mL.

B. Install bypass chemical feeders in each hydronic system where indicated.

1. Install in upright position with top of funnel not more than 48 inches (1200 mm) above the floor.
2. Install feeder in minimum NPS 3/4 (DN 20) bypass line, from main with full-size, fullport, ball valve in the main between bypass connections.
3. Install NPS 3/4 (DN 20) pipe from chemical feeder drain to nearest equipment drain and include a full-size, full-port, ball valve.

C. Fill system with fresh water and add liquid alkaline compound with emulsifying agents and detergents to remove grease and petroleum products from piping. Circulate solution for a minimum of 24 hours, drain, clean strainer screens, and refill with fresh water.

D. Add initial chemical treatment and maintain water quality in ranges noted above for the first year of operation.

E. Fill systems that have antifreeze or glycol solutions with the following concentrations:

1. Chilled-Water Piping: Minimum of 25 percent [ethylene].

3.9 IDENTIFICATION

A. Identify system components. Comply with requirements for identification materials and installation in Section 230553 "Identification for HVAC Piping and Equipment."

3.10 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
 2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
 3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
 4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
 5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.
- B. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

C. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
7. Verify lubrication of motors and bearings.

END OF SECTION 232113

SECTION 232116 - HYDRONIC PIPING SPECIALTIES

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. Hydronic specialty valves.
2. Air-control devices.
3. Strainers.
4. Connectors.

B. Related Requirements:

1. Section 230516 "Expansion Fittings and Loops for HVAC Piping" for expansion fittings and loops.
2. Section 230523.11 "Globe Valves for HVAC Piping" for specification and installation requirements for globe valves common to most piping systems.
3. Section 230523.12 "Ball Valves for HVAC Piping" for specification and installation requirements for ball valves common to most piping systems.
4. Section 230523.13 "Butterfly Valves for HVAC Piping" for specification and installation requirements for butterfly valves common to most piping systems.
5. Section 230523.14 "Check Valves for HVAC Piping" for specification and installation requirements for check valves common to most piping systems.
6. Section 230523.15 "Gate Valves for HVAC Piping" for specification and installation requirements for gate valves common to most piping systems.
7. Section 230923.11 "Control Valves" for automatic control valve and sensor specifications, installation requirements, and locations.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product:

1. Include construction details and material descriptions for hydronic piping specialties.
2. Include rated capacities, operating characteristics, and furnished specialties and accessories.

3. Include flow and pressure drop curves based on manufacturer's testing for calibrated orifice balancing valves and automatic flow-control valves.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For hydronic piping specialties to include in emergency, operation, and maintenance manuals.

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Differential Pressure Meter: For each type of balancing valve and automatic flow control valve, include flowmeter, probes, hoses, flow charts, and carrying case.

1.6 QUALITY ASSURANCE

- A. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.
- B. Safety Valves and Pressure Vessels: Shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 2 - PRODUCTS

2.1 HYDRONIC SPECIALTY VALVES

- A. Bronze, Calibrated-Orifice, Balancing Valves:
 1. Body: Bronze, ball or plug type with calibrated orifice or venturi.
 2. Ball: Brass or stainless steel.
 3. Plug: Resin.
 4. Seat: PTFE.
 5. End Connections: Threaded or socket.
 6. Pressure Gage Connections: Integral seals for portable differential pressure meter.
 7. Handle Style: Lever, with memory stop to retain set position.
 8. CWP Rating: Minimum 125 psig (860 kPa).
 9. Maximum Operating Temperature: 250 deg F (121 deg C).
- B. Cast-Iron or Steel, Calibrated-Orifice, Balancing Valves:
 1. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
 2. Ball: Brass or stainless steel.
 3. Stem Seals: EPDM O-rings.
 4. Disc: Glass and carbon-filled PTFE.
 5. Seat: PTFE.
 6. End Connections: Flanged or grooved.

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HYDRONIC PIPING SPECIALTIES

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7. Pressure Gage Connections: Integral seals for portable differential pressure meter.
 8. Handle Style: Lever, with memory stop to retain set position.
 9. CWP Rating: Minimum **125 psig (860 kPa)**.
 10. Maximum Operating Temperature: **250 deg F (121 deg C)**.
- C. Diaphragm-Operated, Pressure-Reducing Valves: ASME labeled.
1. Body: Bronze or brass.
 2. Disc: Glass and carbon-filled PTFE.
 3. Seat: Brass.
 4. Stem Seals: EPDM O-rings.
 5. Diaphragm: EPT.
 6. Low inlet-pressure check valve.
 7. Inlet Strainer: Removable without system shutdown.
 8. Valve Seat and Stem: Noncorrosive.
 9. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.
- D. Diaphragm-Operated Safety Valves: ASME labeled.
1. Body: Bronze or brass.
 2. Disc: Glass and carbon-filled PTFE.
 3. Seat: Brass.
 4. Stem Seals: EPDM O-rings.
 5. Diaphragm: EPT.
 6. Wetted, Internal Work Parts: Brass and rubber.
 7. Inlet Strainer: Removable without system shutdown.
 8. Valve Seat and Stem: Noncorrosive.
 9. Valve Size, Capacity, and Operating Pressure: Comply with ASME Boiler and Pressure Vessel Code: Section IV, and selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.
- E. Automatic Flow-Control Valves:
1. Body: Brass or ferrous metal.
 2. Flow Control Assembly, provide either of the following:
 - a. Piston and Spring Assembly: [**Corrosion resistant**], tamper proof, self-cleaning, and removable.
 - b. Elastomeric Diaphragm and Polyphenylsulfone Orifice Plate: Operating ranges within **2- to 80-psig (14- to 550-kPa)** differential pressure.
 3. Combination Assemblies: Include bronze or brass-alloy ball valve.
 4. Identification Tag: Marked with zone identification, valve number, and flow rate.
 5. Size: Same as pipe in which installed.
 6. Performance: Maintain constant flow within plus or minus 10 percent, regardless of system pressure fluctuations.
 7. Minimum CWP Rating: [**175 psig (1207 kPa)**]
 8. Maximum Operating Temperature: [**200 deg F (93 deg C)**].

2.2 AIR-CONTROL DEVICES

A. Manual Air Vents:

1. Body: Bronze.
2. Internal Parts: Nonferrous.
3. Operator: Screwdriver or thumbscrew.
4. Inlet Connection: **NPS 1/2 (DN 15)**.
5. Discharge Connection: **NPS 1/8 (DN 6)**.
6. CWP Rating: **150 psig (1035 kPa)**.
7. Maximum Operating Temperature: **225 deg F (107 deg C)**.

B. Automatic Air Vents:

1. Body: Bronze or cast iron.
2. Internal Parts: Nonferrous.
3. Operator: Noncorrosive metal float.
4. Inlet Connection: **NPS 1/2 (DN 15)**.
5. Discharge Connection: **NPS 1/4 (DN 8)**.
6. CWP Rating: **150 psig (1035 kPa)**.
7. Maximum Operating Temperature: **240 deg F (116 deg C)**.

C. Expansion Tanks:

1. Tank: Welded steel, rated for **125-psig (860-kPa)** working pressure and **375 deg F (191 deg C)** maximum operating temperature, with taps in bottom of tank for tank fitting and taps in end of tank for gage glass. Tanks shall be factory tested after taps are fabricated and shall be labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
2. Air-Control Tank Fitting: Cast-iron body, copper-plated tube, brass vent tube plug, and stainless-steel ball check, **100-gal. (379-L)** unit only; sized for compression-tank diameter. Provide tank fittings for **125-psig (860-kPa)** working pressure and **250 deg F (121 deg C)** maximum operating temperature.
3. Tank Drain Fitting: Brass body, nonferrous internal parts; **125-psig (860-kPa)** working pressure and **240 deg F (116 deg C)** maximum operating temperature; constructed to admit air to compression tank, drain water, and close off system.
4. Gage Glass: Full height with dual manual shutoff valves, **[3/4-inch- (20-mm-)]** diameter gage glass, and slotted-metal glass guard.

D. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

E. Tangential-Type Air Separators:

1. Tank: Welded steel; ASME constructed and labeled for **125-psig (860-kPa)** minimum working pressure and **375 deg F (191 deg C)** maximum operating temperature.
2. Air Collector Tube: Perforated stainless steel, constructed to direct released air into expansion tank.
3. Tangential Inlet and Outlet Connections: Threaded for **NPS 2 (DN 50)** and smaller; flanged connections for **NPS 2-1/2 (DN 65)** and larger.
4. Blowdown Connection: Threaded.

5. Size: Match system flow capacity.

2.3 STRAINERS

A. Y-Pattern Strainers:

1. Body: ASTM A126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for **NPS 2 (DN 50)** and smaller; flanged ends for **NPS 2-1/2 (DN 65)** and larger.
3. Strainer Screen: Stainless-steel, **[60]**-mesh strainer, or perforated stainless-steel basket.
4. CWP Rating: **125 psig (860 kPa)**.

2.4 CONNECTORS

A. Stainless-Steel Bellow, Flexible Connectors:

1. Body: Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
2. End Connections: Threaded or flanged to match equipment connected.
3. Performance: Capable of **3/4-inch (20-mm)** misalignment.
4. CWP Rating: **150 psig (1035 kPa)**.
5. Maximum Operating Temperature: **250 deg F (121 deg C)**.

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

- A. Install shut off-duty valves at each branch connection to supply mains and at supply connection to each piece of equipment.
- B. Install **[calibrated-orifice, balancing]** valves at each branch connection to return main.
- C. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.
- D. Install check valves at each pump discharge and elsewhere as required to control flow direction.
- E. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.
- F. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

3.2 HYDRONIC SPECIALTIES INSTALLATION

- A. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.
- B. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting.
- C. Install piping from boiler air outlet, air separator, or air purger to expansion tank with a 2 percent upward slope toward tank.
- D. Install in-line air separators in pump suction. Install drain valve on air separators **NPS 2 (DN 50)** and larger.
- E. Install tangential air separator in pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.
- F. Install expansion tanks above the air separator. Install tank fitting in tank bottom and charge tank. Use manual vent for initial fill to establish proper water level in tank.
 - 1. Install tank fittings that are shipped loose.
 - 2. Support tank from floor or structure above with sufficient strength to carry weight of tank, piping connections, fittings, plus tank full of water. Do not overload building components and structural members.
- G. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure that tank is properly charged with air to suit system Project requirements.

END OF SECTION 232116

SECTION 232123 - HYDRONIC PUMPS

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. Close-coupled, in-line centrifugal pumps.
 - 2. Close-coupled, end-suction centrifugal pumps.

1.3 DEFINITIONS

- A. ECM: Electronically commutated motor.
- B. EPDM: Ethylene propylene diene monomer.
- C. EPR: Ethylene propylene rubber.
- D. FKM: Fluoroelastomer polymer.
- E. HI: Hydraulic Institute.
- F. NBR: Nitrile rubber or Buna-N.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of pump.
 - 1. Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated.
 - 2. Indicate pump's operating point on curves.
- B. Shop Drawings: For each pump.
 - 1. Show pump layout and connections.

2. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.
3. Include diagrams for power, signal, and control wiring.

C. Delegated-Design Submittal: For each pump.

1. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
 - a. Design Calculations: Calculate requirements for selecting vibration isolators [**and seismic restraints**] and for designing vibration isolation bases.
 - b. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.
- B. Seismic Qualification Data: Certificates for pumps, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

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

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Mechanical Seals: [**One**] mechanical seal(s) for each pump.

PART 2 - PRODUCTS

- 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. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design vibration isolation [**and seismic restraints**].
- C. Seismic Performance: Pumps shall withstand the effects of earthquake motions determined in accordance with [**ASCE/SEI 7**].
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified [**and the unit will be fully operational after the seismic event**]."
 - 2. Component Importance Factor: [**1.5**].
 - 3.

2.2 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

- A. Source Limitations: Obtain pumps from single source from single manufacturer.
- B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, inline pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. C. Pump Construction:
 - 1. Casing: Radially split, cast iron, with threaded gauge tappings at inlet and outlet [**replaceable bronze wear rings,**] and threaded [**union-end**] connections.
 - 2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.
 - 3. Pump Shaft Sleeve: [**Type 304 stainless steel**].
 - 4. Pump Stub Shaft: [**Type 316**] stainless steel.
 - 5. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**EPDM**] rubber bellows and gasket. Include water slinger on shaft between motor and seal.
 - 6. Seal Flushing: Flush, cool, and lubricate pump seal by directing pump discharge water to flow over the seal.
- D. Shaft Coupling: Rigid, axially-split spacer coupling to allow service of pump seal without disturbing pump or motor.
- E. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Enclosure: [**Totally enclosed, fan cooled**].
2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. [**Variable**]-speed motor.
6. Provide integral pump motor variable-speed controller.

2.3 CLOSE-COUPLED, END-SUCTION CENTRIFUGAL PUMPS

- A. Source Limitations: Obtain pumps from single source from single manufacturer.
- B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, end suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally. C. Pump Construction:
 1. Casing: Radially split, cast iron, with [**replaceable bronze wear rings,**] drain plug at bottom and air vent at top of volute, threaded gauge tappings at inlet and outlet, and [**flanged**] connections.
 2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.
 3. Pump Shaft Sleeve: [**Type 304 stainless steel**].
 4. Pump Stub Shaft: [**Type 316**] stainless steel.
 5. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and [**EPDM**] bellows and gasket. Include water slinger on shaft between motor and seal.
- D. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 1. Enclosure: [**Totally enclosed, fan cooled**].
 2. NEMA Premium Efficient motors as defined in NEMA MG 1.
 3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
 5. [**Variable**]-speed motor.
 6. Provide integral pump motor variable-speed controller.

2.4 PUMP SPECIALTY FITTINGS

A. Suction Diffuser:

1. Angle pattern.
2. **[300-psig (2060-kPa)]** pressure rating, **[ductile]**-iron body and end cap, pump-inlet fitting.
3. Bronze 16-mesh wire startup and **[Type 304 stainless steel]** permanent strainers with **3/16-inch (4.8-mm) perforations and 51 percent open area**.
4. **[Type 304 stainless steel]** straightening vanes.
5. Drain plug.
6. Factory-fabricated support.

B. Triple-Duty Valve:

1. Angle or straight pattern.
2. **[300-psig (2060-kPa)]** pressure rating, **[ductile]**-iron body, pump-discharge fitting.
3. Valve with multi-turn stem and memory stop to allow valve to be returned to its original position after shutoff.
4. Brass valve disc with EPDM rubber seat.
5. Type 304 stainless steel valve stem.
6. Drain plug and bronze-fitted shutoff, balancing, and check valve features.
7. Brass gauge ports with integral check valve and orifice for flow measurement.

2.5 INTEGRAL PUMP MOTOR VARIABLE-SPEED CONTROLLERS

A. Where specified or scheduled, provide pumps with an integral pump motor speed controller.

1. Motor: Operates as constant- or variable-speed pump with speed regulated by an integrated variable-speed drive.
2. Integrated Pump Controller: Supports direct communication with the building management system (BMS) with built-in support for the following protocols: **[BACnet MS/TP]**.
3. Commissioning and pump set up access to pump controls via the following:
 - a. A web interface (data exchange).
 - b. A user interface located on the face of speed controller to adjust modes and mode values.
 - c. An electronic display that reads real-time mode set values, flow, head, speed, and power and that locks out unauthorized adjustment of pump.
4. Provide electronics with "Auto" as factory default but slope of the proportional curve will automatically match the required system curve, constant pressure control (delta-p/c), variable differential pressure control (delta-p/v), constant curve duty (uncontrolled pump), and rpm regulation. RPM (speed) regulation can be accomplished by the following:

- a. Manual (via user interface or HTML).
 - b. Remote via 0 to 10 V dc.
 - c. Data protocol communications with the BMS.
- 5. Pump Electronics: Standard with multiple digital inputs and one external digital output to be available for additional mechanical room control and pump status monitoring.
- 6. Controller: Mounted on or adjacent to the motor. Provide enclosure rated to UL Type 12.
- 7. Electronically Protected Pumps: Rated for continuous duty and with built-in startup circuit. Provide overcurrent, line surge and current limit protection, thermal monitoring, heat sink status and over temperature protection.
- 8. Pump capable of being monitored continuously via integrated Internet link.
- 9. Integrated pump controller system to have the following features:
 - a. Controller software shall be capable of sensorless control in variable-volume systems without need for pump-mounted (internal/external) or remotely mounted differential pressure sensor.
 - b. Integrated Pump Controller Sensorless Control: Operates under Quadratic Pressure Control (QPC) to ensure that head reduction with reducing flow conforms to quadratic control curve.
 - c. Controller:
 - 1) Minimum head of 40 percent of design duty head.
 - 2) User-adjustable control mode settings and minimum/maximum head set points using built-in programming interface.
 - d. Controller Integrated Control Software:
 - 1) Capable of controlling pump performance for non-overloading power at every point of operation.
 - 2) Capable of maintaining flow rate data.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.
- C. Examine foundations and inertia bases for suitable conditions where pumps will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PUMP INSTALLATION

- A. Comply with [HI 1.4] [and] [HI 2.4].
- B. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.
- C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.
- D. Equipment Mounting:
 - 1. Install base-mounted pumps on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
 - 2. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- E. Equipment Mounting: Install in-line pumps with continuous-thread hanger rods and [spring hangers with vertical-limit stop] of size required to support weight of in-line pumps.
 - 1. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 2. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

3.3 ALIGNMENT

- A. Engage a factory-authorized service representative to perform alignment service.
- B. Perform alignment service. When required by manufacturer to maintain warranty coverage, engage a factory-authorized service representative to perform it.
- C. Comply with requirements in HI standards for alignment of pump and motor shaft. Add shims to the motor feet and bolt motor to base frame. Do not use grout between motor feet and base frame.
- D. Comply with pump and coupling manufacturers' written instructions.
- E. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.4 PIPING CONNECTIONS

- A. Where installing piping adjacent to pump, allow space for service and maintenance.

- B. Connect piping to pumps. Install valves that are same size as piping connected to pumps.
- C. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.
- D. Install [**check valve and throttling valve with memory stop**] on discharge side of pumps.
- E. Install [**Y-type strainer**] and shutoff valve on suction side of pumps.
 - 1. Use startup strainer for initial system startup. Install permanent strainer element before turnover of system to Owner.
- F. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.
- G. Install pressure gauges on pump suction and discharge or at integral pressure-gauge tapping, or install single gauge with multiple-input selector valve.

3.5 ELECTRICAL CONNECTIONS

- A. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.
- D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 - 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least **1/2 inch (13 mm)** high.

3.6 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.7 STARTUP SERVICE

- A. **[Engage a factory-authorized service representative to perform]** startup service.
1. Complete installation and startup checks in accordance with manufacturer's written instructions.
 2. Check piping connections for tightness.
 3. Clean strainers on suction piping. Use startup strainer for initial startup.
 4. Perform the following startup checks for each pump before starting:
 - a. Verify bearing lubrication.
 - b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
 - c. Verify that pump is rotating in correct direction.
 5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.
 6. Start motor.
 7. Open discharge valve slowly.

3.8 FIELD QUALITY CONTROL

- A. Testing Agency: **[Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform tests and inspections **[with the assistance of a factory-authorized service representative]**.
- D. Hydronic pumps will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.9 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train]** Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

END OF SECTION 232123

SECTION 232513 - WATER TREATMENT FOR CLOSED-LOOP HYDRONIC SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

- A. Section includes the following water treatment for closed-loop hydronic systems:
 - 1. **[Automatic]** chemical-feed equipment.
 - 2. Chemicals.
- B. Related Requirements:
 - 1. Section 232533 "HVAC Makeup-Water Filtration Equipment" for water treatment of water softeners, RO equipment, and filtration equipment.

1.3 DEFINITIONS

- A. RO: Reverse osmosis.
- B. TDS: Total dissolved solids consist of salts and other materials that combine with water as a solution.
- C. TSS: Total suspended solids include both organic and inorganic solids that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, operating characteristics, and furnished specialties and accessories for the following products:
 - 1. Bypass feeders.
 - 2. Water meters.
 - 3. Inhibitor injection timers.
 - 4. pH controllers.
 - 5. Chemical solution tanks.
 - 6. Injection pumps.
 - 7. Chemical-treatment test equipment.

8. Chemical material safety data sheets.
9. Inhibited ethylene glycol.
10. Inhibited propylene glycol.

Shop Drawings: Pretreatment and chemical-treatment equipment, showing tanks, maintenance space required, and piping connections to hydronic systems.

1. Include plans, elevations, sections, and attachment details.
2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Certificates: For components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

B. Water-Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider. C. Field quality-control reports.

D. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article. E. Water Analysis: Illustrate water quality available at Project site.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water treatment service provider, capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Provide all hardware, chemicals, and other material necessary to maintain HVAC water quality in all systems, as indicated in this Specification. Water quality for hydronic systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of hydronic equipment without creating a hazard to operating personnel or the environment.

Base HVAC water treatment on quality of water available at Project site, hydronic system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

- C. Closed hydronic systems, including [**chilled water**] shall have the following water qualities:

1. pH: Maintain a value within **<as per ASHRAE and specialist>**.
2. Alkalinity: Maintain a value within **< as per ASHRAE and specialist > mg/L as CaCO₃**.
3. Steel Corrosion Inhibitors: Provide sufficient inhibitors to limit mild steel corrosion to **< as per ASHRAE and specialist > mils per year**. Maintain soluble iron concentrations at or below **< as per ASHRAE and specialist > mg/L**.
4. Yellow Metal Corrosion Inhibitor: Provide sufficient copper and brass corrosion inhibitors to limit copper corrosion to **< as per ASHRAE and specialist > mils per year**. Maintain soluble copper concentrations at or below **< as per ASHRAE and specialist > mg/L**.
5. Scale Control: Provide softened water for initial fill and makeup. [**Where softened water is not used, provide sufficient scale inhibitors to prevent formation of scale and maintain all scale-forming material in solution.**]
6. Dispersants: Provide sufficient dispersants to prevent sedimentation of fine particulate matter.
7. Microbiological Limits:
 - a. Total Aerobic Plate Count: Maintain a maximum value of **< as per ASHRAE and specialist > organisms/mL**.
 - b. Total Anaerobic Plate Count: Maintain a maximum value of **< as per ASHRAE and specialist > organisms/mL**.
 - c. Nitrate Reducers: Maintain a maximum value of **< as per ASHRAE and specialist > organisms/mL**.
 - d. Sulfate Reducers: Maintain a maximum value of **< as per ASHRAE and specialist > organisms/mL**.
 - e. Iron Bacteria: Maintain a maximum value of **< as per ASHRAE and specialist > organisms/mL**.

2.2 AUTOMATIC CHEMICAL-FEED EQUIPMENT

- A. Water Meter, Piston Type, Threaded:

1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.

2. Body: Bronze.
3. Minimum Working-Pressure Rating: 150 psig (1035 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Threaded.
7. **[Controls: Flow-control switch with normally open contacts, rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.]**
8. **[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.]**

Water Meter, Turbine Type, Threaded:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 100 psig (690 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Threaded.
7. **[Controls: Flow-control switch with normally open contacts. rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.]**
8. **[Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.]**

C. Water Meter, Turbine Type, Flanged:

1. AWWA C701, turbine-type, totalization meter.
2. Body: **[Bronze]**.
3. Minimum Working-Pressure Rating: 150 psig (1035 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Flanged.
7. **[Controls: Flow-control switch with normally open contacts, rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.]**
8. **[Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.]**

D. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: **[120 gal. (454 L)]**.

E. Chemical Solution Injection Pumps:

1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

F. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A269/A269M, Type 304 stainless steel for steam boiler injection assemblies.

G. Injection Assembly:

1. Quill: Minimum **NPS 1/2 (DN 15)** with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: **[Two]**-piece, stainless steel; selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum **600 psig (4137 kPa)** at **200 deg F (93 deg C)**.

2.3 CHEMICAL-TREATMENT TEST EQUIPMENT

- A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounted cabinet for testing pH, corrosion inhibitors, alkalinity, hardness, and other properties recommended by manufacturer.
- B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.
1. **[Two]** station rack for closed-loop systems.

2.4 CHEMICALS

- A. Chemicals shall be as recommended by water-treatment system manufacturer, compatible with piping system components and connected equipment, and able to attain water quality specified in "Performance Requirements" Article.

2.5 INHIBITED ETHYLENE GLYCOL AND PROPYLENE GLYCOL

A. Inhibited Ethylene Glycol:

1. Ethylene glycol with inhibitor additive, to provide freeze protection for heat-transfer fluid and corrosion protection for carbon-steel, brass, copper, stainless steel, and cast-iron piping and fittings.
2. Inhibitor creates a passive layer on all surfaces that contact ethylene glycol to prevent corrosion and stabilizes fluid pH, to compensate for acids formed from glycol degradation.
3. pH value shall be maintained between **[9.0 and 10.5]**, with reserve alkalinity greater than **12 mL**.
4. Concentrated inhibited ethylene glycol is to be 95.5 percent ethylene glycol by weight and 4.5 percent performance additives.
5. Concentrated inhibited ethylene glycol is mixed with water in proper proportion specified by the manufacturer to provide freeze protection to **[minus 20 deg F (minus 29 deg C)]**. Premixed heat-transfer fluid may be used, or glycol/water mixture may be prepared at time of installation. Use only deionized water for mixing.
6. Provide only ethylene glycol that is specifically blended for HVAC application. Automotive-type antifreeze is unacceptable.

B. Inhibited Propylene Glycol:

1. Propylene glycol with inhibitor additive, to provide freeze protection for heat-transfer fluid and corrosion protection for carbon steel, brass, copper, stainless steel, and cast-iron piping and fittings.
2. Inhibitor creates a passive layer on all surfaces that contact propylene glycol to prevent corrosion and stabilizes fluid pH, to compensate for acids formed from glycol degradation.
3. pH value shall be maintained, with reserve alkalinity greater than **< as per ASHRAE and specialist > mL**.
4. Concentrated inhibited propylene glycol is to be 95.5 percent propylene glycol by weight and 4.5 percent performance additives.
5. Concentrated inhibited propylene glycol is mixed with water in proper proportion specified by the manufacturer to provide freeze protection to **[minus 20 deg F (minus 29 deg C)]**. Premixed heat-transfer fluid may be used, or glycol/water mixture may be prepared at the time of installation. Use only deionized water for mixing.
6. Provide only propylene glycol that is specifically blended for HVAC application. Automotive-type antifreeze is unacceptable.

PART 3 - EXECUTION

3.1 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION

- A. Install chemical-application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate. Install all chemical application equipment within a spill-containment area without floor drain.
- B. Install seismic restraints for equipment and floor-mounting accessories, and anchor to building structure. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install water-testing equipment on wall near water-chemical-application equipment.
- D. Install interconnecting control wiring for chemical-treatment controls and sensors.
- E. Mount sensors and injectors in piping circuits.
- F. Bypass Feeders: Install in closed hydronic systems, including [**chilled water**] and equip with the following:
 - 1. Install bypass feeder in a bypass circuit around circulating pumps unless indicated otherwise on Drawings.
 - 2. Install water meter in makeup-water supply.
 - 3. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 - 4. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below the feeder inlet.
 - 5. Install a swing check on the inlet after the isolation valve.
- G. Install automatic fluid make-up equipment for glycol water system, and include the following:
 - 1. Chemical solution tanks.
 - 2. Chemical solution injection pumps.
 - 3. Water meter in makeup supply to system.
 - 4. Pressure switch to operate injection pump as necessary to maintain glycol system pressure.

3.3 PIPING CONNECTIONS

- A. Piping installation requirement are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to equipment, allow space for service and maintenance.
- C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Section 232113 "Hydronic Piping."

- D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- E. Comply with requirements in Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.

3.4 ELECTRICAL CONNECTIONS

- A. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Owner will engage a qualified testing agency to perform tests and inspections.
- B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- C. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- D. Perform tests and inspections [**with the assistance of a factory-authorized service representative**].
- E. Tests and Inspections:
 - 1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
 - 2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 - 3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of hydronic systems' startup procedures.
 - 4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 - 5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 - 6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
 - 7. Cap and subject piping to static water pressure of **50 psig (345 kPa)** above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.

8. Repair leaks and defects with new materials, and retest piping until no leaks exist. F.

Equipment will be considered defective if it does not pass tests and inspections.

- G. Prepare test and inspection reports.
- H. At **[four]** week intervals following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis, advising Owner of changes necessary to adhere to "Performance Requirements" Article.
- I. Comply with ASTM D3370 and with the following standards:
 1. Silica: ASTM D859.
 2. Acidity and Alkalinity: ASTM D1067.
 3. Iron: ASTM D1068.
 4. Water Hardness: ASTM D1126.

3.6 MAINTENANCE SERVICE

- A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above, to inhibit corrosion and scale formation for hydronic piping and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion and shall include the following:
 1. Initial water analysis and HVAC water-treatment recommendations.
 2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
 3. Periodic field service and consultation.
 4. Customer report charts and log sheets.
 5. Laboratory technical analysis.
 6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

3.7 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train]** Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

END OF SECTION 232513

SECTION 232533 - HVAC MAKEUP-WATER FILTRATION EQUIPMENT

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 HVAC water-filtration equipment:
 - 1. HVAC makeup-water softeners.
 - 2. Multimedia filters.
 - 3. Self-cleaning strainers.
 - 4. Bag- or cartridge-type filters.
 - 5. Water-softener chemicals.
- B. Related Requirements:
 - 1. Section 232513 "Water Treatment for Closed-Loop Hydronic Systems" for hydronic water-treatment equipment.

1.3 DEFINITIONS

- A. TSS: Total suspended solids include both organic and inorganic solids that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, operating characteristics, and furnished specialties and accessories for the following products:
 - 1. Water softeners.
 - 2. Multimedia filters.
 - 3. Self-cleaning strainers.
 - 4. Bag- or cartridge-type filters.
- B. Shop Drawings: Softeners and filtration equipment, maintenance space required, and piping connections to HVAC systems.
 - 1. Include plans, elevations, sections, and attachment details.

2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For **[water softeners]** **[water-filtration units]** and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Water-Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.
- C. Field quality-control reports.
- D. Water Analysis: Illustrate water quality available at Project site.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sensors, injection pumps, **[water softeners]** **[water filtration units]** and controllers to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 HVAC MAKEUP-WATER SOFTENER

- A. Description: Twin mineral tanks and one brine tank, factory mounted on skid.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure, as recommended in writing by manufacturer.
- D. Mineral Tanks:
 1. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 2. Fabricate and label fiber-reinforced plastic (FRP) filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
 3. Pressure Rating: **[150 psig (1035 kPa)]** minimum.
 4. Wetted Components: Suitable for water temperatures from **[40 to at least 100 deg F (5 to at least 38 deg C)]**.

5. Freeboard: 50 percent, minimum, for backwash expansion above the normal resin bed level.
6. Support Legs or Skirt: Constructed of structural steel, welded or bonded to tank before testing and labeling.
7. Finish: Hot-dip galvanized on exterior and interior of tank after fabrication.
8. Upper Distribution System: Single-point type, fabricated from galvanized-steel pipe and fittings.
9. Lower Distribution System: Hub and radial-arm or header-lateral type; fabricated from PVC pipe and fittings with individual, fine-slotted, nonclogging polyethylene strainers; arranged for even-flow distribution through resin bed.

E. Controls: Automatic; factory mounted on mineral tanks and factory wired.

1. Adjustable duration of regeneration steps.
2. Push-button start and complete manual operation override.
3. Pointer on pilot-control valve shall indicate cycle of operation.
4. Means of manual operation of pilot-control valve if power fails.
5. Main Operating Valves: Industrial, automatic, multiport, diaphragm type with the following features:
 - a. Slow opening and closing, nonslam operation.
 - b. Diaphragm guiding on full perimeter from fully open to fully closed.
 - c. Isolated dissimilar metals within valve.
 - d. Self-adjusting, internal, automatic brine injector that draws brine and rinses at constant rate independent of pressure.
 - e. Float-operated brine valve to automatically measure the correct amount of brine to the softener and refill with fresh water.
 - f. Sampling cocks for soft water.
6. Flow Control: Automatic control of backwash and flush rates over variations in operating pressures that do not require field adjustments. Equip mineral tanks with automatic-resethead water meter that electrically activates cycle controller to initiate regeneration at preset total in **gallons (liters)** and that automatically resets after regeneration to preset total in **gallons (liters)** for next service run. Include alternator to regenerate one mineral tank with the other in service.

F. Brine Tank: Combination measuring and wet-salt storing system.

1. Tank and Cover Material: Fiberglass a minimum of **3/16 inch (4.8 mm)** thick; or molded polyethylene a minimum of **3/8 inch (9.5 mm)** thick.
2. Brine Valve: Float operated and plastic fitted for automatic control of brine withdrawn and freshwater refill.
3. Size: Large enough for at least four regenerations at full salting.

G. Factory-Installed Accessories:

1. Piping, valves, tubing, and drains.
 2. Sampling cocks.
 3. Main-operating-valve position indicators.
 4. Water meters.
- H. Water Test Kit: Include in wall-mounted enclosure for water softener.
- I. Capacities and Characteristics:
- a. **As per schedule of equipment.**

2.2 MULTIMEDIA FILTERS

- A. Description: Factory-fabricated and -tested, simplex, multimedia filter system, consisting of filter tank, media, strainer, circulating pump, piping, and controls for removing particles from water.
1. Filter Tank: Corrosion resistant with distribution system and media.
 - a. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - b. Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
 - c. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded in accordance with ASME B1.20.1.
 - d. Steel Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges in accordance with ASME B16.5 or grooved in accordance with AWWA C606.
 - e. FRP Tank Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Type A, integral; **[Designation F, 150-psig (1.034-MPa)]** pressure category flanges of grade same as tank material in accordance with ASTM D5421.
 2. Motorized Valves: Flanged or grooved-end, ductile-iron butterfly type with **[EPDM]** valve seat and stem seal; with ASTM B148 aluminum bronze disc.
 3. Strainer: Basket type mounted on pump suction.
 4. Piping: ASTM A53/A53M; Type S, F, or E; Grade B; Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
 5. Safety Valves: Automatic pressure relief.
 6. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
 - a. Casing: Radially split, cast iron.
 - b. Pressure Rating: **[125 psig (860 kPa)] [150 psig (1035 kPa)]** minimum.
 - c. Impeller: ASTM B584 cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
 - d. Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
 - e. Seal: Mechanical.

- f. Motor: Open, dripproof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- 7. Controls: Automatic control of circulating pump and tank backwash; factory wired for single electrical connection.
 - a. Panel: NEMA 250, [Type 4] enclosure with time clock and pressure gages.
 - b. Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
 - c. Backwash: Automatic; with time clock and differential pressure switch.
 - d. Backwash Valve: Tank mounted with valves interlocked to single actuator.
- 8. Support: Skid mounting. **[Fabricate supports, base, and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event, when filter base is anchored to building structure.]**
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Capacities and Characteristics:
 - a. **As per schedule of equipment.**

2.3 SELF-CLEANING STRAINERS

- A. Description: Factory-fabricated and -tested, ASTM A126, Class B, cast-iron or steel, selfcleaning strainer system of tank, strainer, backwash arm or cleaning spiral, drive and motor, piping, and controls for removing particles from water.
 - 1. Fabricate and label ASTM A126, Class B, cast-iron or steel strainer tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - 2. Pipe Connections:
 - a. **NPS 2 (DN 50)** and Smaller: Threaded in accordance with ASME B1.20.1.
 - b. **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges in accordance with ASME B16.5 or grooved according to AWWA C606.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Motorized Valves: Flanged or grooved-end, ductile-iron angle type with [EPDM] valve seat and stem seal; with ASTM B148 aluminum bronze disc.
- D. Strainer: Stainless steel.

- E. Piping: ASTM A53/A53M; Type S, F, or E; Grade B; Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
- F. Safety Valves: Automatic pressure relief.
- G. Backwash Arm Drive:
 - 1. Drive Casing: Cast iron.
 - 2. Worm Gears: Immersed in oil.
 - 3. Motor: Open, dripproof motor supported on the strainer-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- H. Controls: Automatic control of backwash; factory wired for single electrical connection.
 - 1. Panel: NEMA 250, [Type 4] enclosure with time clock and pressure gages.
 - 2. Backwash Arm Drive: Automatic and manual switching; manual switch position bypasses safeties and controls.
 - 3. Backwash: Automatic; with time clock and differential pressure switch.
 - 4. Backwash Valve: Electric actuator.
- I. Support: Skid mounting. **[Fabricate supports, base, and attachment to tank with reinforcement strong enough to resist strainer movement during a seismic event, when strainer base is anchored to building structure.]**
- J. Capacities and Characteristics:
 - a. **As per schedule of equipment.**

2.4 [CARTRIDGE]-TYPE FILTERS

- A. Description: [Housing] with filter [cartridges] for removing particles from water.
 - 1. Housing: Corrosion resistant; designed to separate inlet from outlet and to direct inlet through [cartridge]-type water filter; with [feet, or skirt].
 - a. Pipe Connections **NPS 2 (DN 50)** and Smaller: Threaded in accordance with ASME B1.20.1.
 - b. Steel Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: Steel, Class 150 flanges in accordance with ASME B16.5 or grooved in accordance with AWWA C606.
 - c. Plastic Housing Pipe Connections **NPS 2-1/2 (DN 65)** and Larger: **150-psig (1035kPa)** plastic flanges.
 - 2. [Cartridge]: Replaceable; of shape to fit housing.

- B. Capacities and Characteristics:
 a. As per schedule of equipment.
- C. Motorized Purge Valve: Gate valve.
1. Motorized Valves: Butterfly-type, flanged or grooved-end, ductile-iron body, with [EPDM] valve seat and stem seal; with ASTM B148 aluminum bronze disc. D. Strainer: Stainless steel basket type mounted on pump suction.
- E. Piping: ASTM A53/A53M; Type S, F, or E; Grade B; Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding or ductile-iron fittings.
- F. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
1. Casing: Radially split, cast iron.
2. Pressure Rating: [150 psig (1035 kPa)] minimum.
3. Impeller: ASTM B584 cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
4. Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
5. Seal: Mechanical.
6. Motor: Open, dripproof motor supported on the pump-bearing frame. General requirements for motors are specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- G. Controls: Automatic control of circulating pump and separator purge; factory wired for single electrical connection.
1. Panel: NEMA 250, [Type 4] enclosure.
2. Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
3. Separator Purge: Automatic and manual.
4. TSS Controller Interlock: Open separator purge valve with bleed-off control.
- H. Support: Skid mounting. [Fabricate supports, base, and attachment to separator housing with reinforcement strong enough to resist separator movement during a seismic event, when separator base is anchored to building structure.]
- I. Capacities and Characteristics:
 a. As per schedule of equipment.

2.5 WATER-SOFTENER CHEMICALS

- A. Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range with good resistance to bead fracture from attrition or shock. Resin exchange capacity shall be a minimum **30,000 grains/cu. ft. (69 kg/cu. m)** of calcium carbonate of resin when regenerated with **15 lb (6.8 kg)** of salt.
- B. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are unacceptable.

PART 3 - EXECUTION

3.1 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION

- A. Equipment Mounting:
 - 1. Install [**water-softener**] [**water-filtration**] equipment on cast-in-place concrete equipment base(s).
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

3.3 WATER-SOFTENER INSTALLATION

- A. Install water-softener equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
- B. Install brine lines and fittings furnished by equipment manufacturer but not factory installed.
- C. Prepare mineral-tank distribution system and underbed for minerals, and place specified mineral into mineral tanks.
- D. Install water-testing sets on wall adjacent to water softeners.

3.4 PIPING CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

- B. Where installing piping adjacent to equipment, allow space for service and maintenance.
- C. Make piping connections between HVAC [**water-softener**] [**water-filtration**] equipment and dissimilar-metal piping with dielectric fittings. Comply with requirements in Section 232113 "Hydronic Piping."
- D. Install shutoff valves on HVAC [**water-softener**] [**water-filtration**] equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- E. Comply with requirements in Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.
- F. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.

3.5 ELECTRICAL CONNECTIONS

- A. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."

3.6 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. Inspect field-assembled components and equipment installation, including piping and electrical connections.
 2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 3. Place HVAC [**water-softener**] [**water-filtration**] system into operation, and calibrate controls during the preliminary phase of HVAC systems' startup procedures.
 4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.

7. Cap and subject piping to static water pressure of **50 psig (345 kPa)** above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
8. Repair leaks and defects with new materials and retest piping until no leaks exist. C.

Equipment will be considered defective if it does not pass tests and inspections.

- D. Prepare test and inspection reports.

3.7 MAINTENANCE SERVICE

- A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above, to inhibit corrosion, scale formation, and biological growth for equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion, and shall include the following:

1. Periodic field service and consultation.
2. Customer report charts and log sheets.
3. Laboratory technical analysis.
4. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

3.8 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train]** Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.
- B. Training: Provide a "how-to-use" self-contained breathing apparatus video that details exact operating procedures of equipment.

END OF SECTION 232533

SECTION 236426.16 - WATER-COOLED, ROTARY-SCREW WATER CHILLERS

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. Packaged, water-cooled, single-compressor chillers.

- B. Related Requirements:

- 1. Section 284400 "Refrigerant Detection and Alarm" for refrigerant monitors, alarms, supplemental breathing apparatus, and ventilation equipment interlocks.

1.3 DEFINITIONS

- A. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
- B. DDC: Direct digital control.
- C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
- D. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by AHRI 550/590 and referenced to AHRI standard rating conditions.
- E. kVA_r: Kilovolt amperes reactive.
- F. **kW/Ton (kW/kW)**: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in **tons (kW)** at any given set of rating conditions.
- G. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by AHRI 550/590 and intended for operating conditions other than AHRI standard rating conditions.
- H. RTD: Resistance temperature detector.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
2. Performance at AHRI standard conditions and at conditions indicated.
3. Performance at AHRI standard unloading conditions.
4. Minimum evaporator flow rate.
5. Refrigerant capacity of chiller.
6. Oil capacity of chiller.
7. Fluid capacity of evaporator.
8. Characteristics of safety relief valves.
9. Fluid capacity of condenser.
10. Minimum entering condenser-fluid temperature.
11. Performance at varying capacities with constant-design, entering condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in [5 deg F (3 deg C)] increments.

B. Sustainable Design Submittals:

1. Follow LEED Requirements

C. 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.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor 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. Structural supports.
2. Piping roughing-in requirements.
3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

B. Certificates: For certification required in "Quality Assurance" Article.

C. Seismic Qualification Data: Certificates, for chillers, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- D. Source quality-control reports.
- E. Field Quality-Control Reports: Startup service reports.
- F. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

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

1.7 QUALITY ASSURANCE

- A. AHRI Certification: Certify chiller according to AHRI 550 certification program.
- B. AHRI Rating: Rate chiller performance according to requirements in AHRI 550/590.
- C. ASHRAE Compliance:
 - 1. ASHRAE 15 for safety code for mechanical refrigeration.
 - 2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.
- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1.
- E. ASME Compliance: Fabricate and label chiller to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and include an ASME U-stamp and nameplate certifying compliance.
- F. Comply with NFPA 70.
- G. Comply with requirements of UL and UL Canada and include label by a qualified testing agency showing compliance.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Ship chillers from the factory fully charged with refrigerant.
- B. Ship each oil-lubricated chiller with a full charge of oil.
 - 1. Ship oil [**factory installed in chiller**].
- C. Package chiller for export shipping in totally enclosed [**crate**] [**and**] [**bagging**].

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.
1. Extended warranties include, but are not limited to, the following:
 - a. Complete chiller including refrigerant and oil charge.
 - b. Complete compressor and drive assembly including refrigerant and oil charge.
 - c. Refrigerant [**and oil**] charge.
 - d. Loss of refrigerant charge for any reason.
 2. Warranty Period: [**Five**] years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Chillers shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7].
1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified [**and the unit will be fully operational after the seismic event**]."
- B. Condenser-Fluid Temperature Performance:
1. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of [**55 deg F (13 deg C)**] and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
 2. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of [**55 deg F (13 deg C)**].
 3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
- C. Site Altitude: Chiller shall be suitable for altitude in which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
- D. Performance Tolerance: Comply with the following in lieu of AHRI 550/590:
1. Allowable Capacity Tolerance: [**Zero**] percent.
 2. Allowable IPLV/NPLV Performance Tolerance: [**Zero**] percent.

2.2 PACKAGED, WATER-COOLED, MULTIPLE-COMPRESSORS CHILLERS

- A. Description: Factory-assembled and [run]-tested chiller with two compressors, compressor motor, compressor motor controller, lubrication system, evaporator, condenser, **controls**, interconnecting unit piping and wiring, and indicated accessories.
 - 1. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
- B. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.
- C. Compressor:
 - 1. Description: [**screw**], and oil lubricated.
 - 2. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
 - 3. Rotors: Manufacturer's standard one-, two-, or three-rotor design.
 - 4. Seals: Seal drive assembly to prevent refrigerant leakage.
- D. Compressor Motor:
 - 1. Continuous-duty, squirrel-cage, induction-type motor with energy efficiency required to suit chiller energy efficiency indicated.
 - 2. Factory mounted, aligned, and balanced as part of compressor assembly before shipping.
 - 3. Motor shall be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.
 - 4. Provide motor with thermistor or RTD in [**single motor winding**] [**each of three-phase motor windings**] to monitor temperature and report information to chiller control panel.
 - 5. Provide motor with thermistor or RTD to monitor bearing temperature and report information to chiller control panel.
- E. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.
 - 1. Overspeed Test: 25 percent above design operating speed.
- F. Service: Easily accessible for inspection and service.
 - 1. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
 - 2. Provide lifting lugs or eyebolts attached to casing.
- G. Capacity Control: Modulating slide-valve assembly or port unloaders combined with [**a variable-frequency controller, and**] hot-gas bypass, if necessary, to achieve performance indicated.
 - 1. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
 - 2. Operating Range: From 100 to [**5**] percent of design capacity.

3. Condenser-Fluid Unloading Requirements over Operating Range: [**Drop-in, entering condenser-fluid temperature of 2.5 deg F (1.4 deg C) drop for each 10 percent in capacity reduction**].
- H. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.
1. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
 2. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.
 3. [**Dual oil filters, one redundant,**] shall be the easily replaceable cartridge type, minimum 0.5-micron efficiency, with means of positive isolation while servicing.
 4. [**Refrigerant- or water**]-cooled oil cooler.
 5. Factory-installed and pressure-tested piping with isolation valves and accessories.
 6. Oil compatible with refrigerant and chiller components.
 7. Positive visual indication of oil level.
- I. Refrigerant Circuit:
1. Refrigerant: Type as indicated on Drawings.
 2. Refrigerant Type: [**R-134a**] [**or**] [**any HFC**] Classified as Safety Group A1 according to ASHRAE 34.
 3. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
 4. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.
 5. Pressure Relief Device:
 - a. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - b. ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type. Pressure relief valve(s) shall be provided for each heat exchanger. Condenser shall have dual valves with one being redundant and configured to allow either valve to be replaced without loss of refrigerant.
 6. Refrigeration Transfer: Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller to a remote refrigerant storage and recycling system. Comply with requirements in ASHRAE 15 and ASHRAE 147.
 7. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line to the condenser and the refrigerant liquid line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell. [**In addition, provide isolation valve on suction side of compressor from evaporator to allow for isolation and storage of full refrigerant charge in the chiller evaporator shell.**]
- J. Evaporator:
1. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.
 2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.

3. Designed to prevent liquid refrigerant carryover from entering compressor.
4. Provide evaporator with sight glass or other form of positive visual verification of liquid-refrigerant level.
5. Tubes:
 - a. Individually replaceable from either end and without damage to tube sheets and other tubes.
 - b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
 - c. Material: **[copper-nickel alloy]**.
 - d. Nominal OD: **[Manufacturer's choice]**.
 - e. Minimum Wall Thickness: **[Manufacturer's choice]**.
 - f. External Finish: Manufacturer's standard.
 - g. Internal Finish: **[Enhanced] [or] [smooth]**.
6. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
7. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
8. Water Box:
 - a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 - b. **[Marine]** type for water box with piping connections. Standard type for water box without piping connections.
 - c. Provide water boxes **[and marine water-box covers]** with lifting lugs or eyebolts.
 - d. **[Hinged] [or] [dovited]** marine water-box covers.
 - e. Nozzle Pipe Connections: **[Grooved with mechanical-joint coupling and flange adapter]**.
 - f. Thermistor or RTD temperature sensor factory installed in each nozzle.
 - g. Fit each water box with **[3/4- or 1-inch (19- or 25-mm)]** drain connection at low point and vent connection at high point, each with threaded plug.
9. Additional Corrosion Protection:
 - a. Electrolytic corrosion-inhibitor anode.
 - b. Coat wetted surfaces with a corrosion-resistant finish.

K. Condenser:

1. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator.
2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
3. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
4. Provide condenser with sight glass or other form of positive visual verification of refrigerant charge and condition.
5. Tubes:

- a. Individually replaceable from either end and without damage to tube sheets and other tubes.
 - b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
 - c. Material: **[copper-nickel alloy]**.
 - d. Nominal OD: **[Manufacturer's choice]**.
 - e. Minimum Wall Thickness: **[Manufacturer's choice]**.
 - f. External Finish: Manufacturer's standard.
 - g. Internal Finish: **[Enhanced] [or] [smooth]**.
6. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
 7. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
 8. Water Box:
 - a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
 - b. **[Marine]** type for water box with piping connections. Standard type for water box without piping connections.
 - c. Provide water boxes **[and marine water-box covers] with** lifting lugs or eyebolts.
 - d. **[Hinged] [or] [davitd]** marine water-box covers.
 - e. Nozzle Pipe Connections: **[Grooved with mechanical-joint coupling and flange adapter]**.
 - f. Thermistor or RTD temperature sensor factory installed in each nozzle.
 - g. Fit each water box with **[3/4- or 1-inch (19- or 25-mm)]** drain connection at low point and vent connection at high point, each with threaded plug.
 9. Additional Corrosion Protection:
 - a. Electrolytic corrosion-inhibitor anode.
 - b. Coat wetted surfaces with a corrosion-resistant finish.

L. Electrical Power:

1. Factory installed and wired, and functionally tested at factory before shipment.
2. Single-point, field-power connection to **[fused disconnect switch] [circuit breaker]**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than **[65,000]** A.
 - a. Provide branch power circuit to each motor, electric heater, dedicated electrical load, and controls **[with disconnect switch or circuit breaker]**.
 - b. NEMA ICS 2-rated motor controller for auxiliary motors, hand-off-auto switch, and overcurrent protection for each motor. Provide variable-frequency controller for each variable-speed motor furnished.
 - c. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered **[and color-coded]** wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.

4. Factory-installed wiring outside of enclosures shall be in metal raceway except make connections to each motor and heater with not more than a **24-inch (610-mm)** length of liquidtight conduit.
5. Factory install and wire capacitor bank for the purpose of power factor correction to **[0.95]** at all operating conditions.
 - a. If capacitors are mounted in a dedicated enclosure, use same NEMA enclosure type as motor controller. Provide enclosure with service entrance knockouts and bushings for conduit.
 - b. Capacitors shall be non-PCB dielectric fluid, metallized electrode design, low loss with low-temperature rise. The kVAR ratings shall be indicated and shall not exceed the maximum limitations set by NFPA 70. Provide individual cells as required.
 - c. Provide each cell with current-limiting replaceable fuses and carbon-film discharge resistors to reduce residual voltage to less than 50 V within one minute after de-energizing.
 - d. Provide a ground terminal and a terminal block or individual connectors for phase connection.

M. Motor Controller:

1. Enclosure: **[Factory installed, unit mounted]**, **[NEMA 250]** **[Type 12]**, with hinged full-front access door **[with lock and key or padlock and key]**.
2. Control Circuit: Obtained from **[integral control power transformer]** with a control power **[transformer]** **[source]** of enough capacity to operate connected control devices.
3. Overload Relay: Shall be sized according to UL 1995 or shall be an integral component of chiller control microprocessor.
4. VFD Controller.
5. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.
 - a. Externally Operated **[, Door-Interlocked]** Disconnect: **[Fused disconnect switch]** **[Circuit breaker]**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than **[65,000]** A.
 - 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: Time-delay relays.
 - e. Elapsed-Time Meters: Numerical readout in hours on face of enclosure.
 - f. Number-of-Starts Counter: Numerical readout on face of enclosure.
 - g. Meters: Panel type, **[4-1/4 inches (108 mm)]** with **[270]**-degree scale and **[1]** percent accuracy. Where indicated, provide transfer device with an off position. Meters shall indicate the following:
 - 1) Ammeter: Output current for each phase, with current sensors rated to suit application.
 - 2) Voltmeter: Output voltage for each phase.
 - 3) Frequency Meter: Output frequency.

- 4) Real-time clock with current time and date.
- 5) Total run time.
- h. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:
 - 1) Selectable, digital display of the following:
 - a) Phase Currents, Each Phase: Plus or minus 1 percent.
 - b) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
 - c) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
 - d) Three-Phase Real Power: Plus or minus 2 percent.
 - e) Three-Phase Reactive Power: Plus or minus 2 percent.
 - f) Power Factor: Plus or minus 2 percent.
 - g) Frequency: Plus or minus 0.5 percent.
 - h) Integrated Demand with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 percent.
 - i) Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.
 - 2) Mounting: Display and control unit flush or semirecessed in instrument compartment door.
- i. Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.
- j. Power Protection: Chiller shall shut down within six cycles of power interruption.

N. Variable-Frequency Controller (VFD):

- 1. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
- 2. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
- 3. Enclosure: Unit mounted, NEMA 250, [**Type 1**], with hinged full-front access door with lock and key.
- 4. Integral Disconnecting Means: [**Door-interlocked,**] UL 489, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [**65,000**] A.
- 5. Technology: Pulse-width-modulated output suitable for constant or variable torque loads.
- 6. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.
- 7. Operating Requirements:
 - a. Input AC Voltage Tolerance: [**380 or 460-V ac, plus 10 percent**].
 - b. Input frequency tolerance of 50 Hz, plus or minus 2 Hz.
 - c. Capable of driving full load, without derating, under the following conditions:
 - 1) Ambient Temperature: 0 to 40 deg C.
 - 2) Relative Humidity: Up to [**95**] percent (noncondensing).

- 3) Altitude: [at sea level].
 - d. Minimum Efficiency: 96 percent at 50 Hz, full load.
 - e. Minimum Displacement Primary-Side Power Factor: 98 percent.
 - f. Overload Capability: 1.05 times the full-load current for seven seconds.
 - g. Starting Torque: As required by compressor-drive assembly.
 - h. Speed Regulation: Plus or minus 1 percent.
 - i. Isolated control interface to allow controller to follow control signal over a 10:1 speed range.
 - j. To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
 - k. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.
- 8. Internal Adjustability Capabilities:
 - a. Minimum Output Frequency: 6 Hz.
 - b. Maximum Output Frequency: 50 Hz.
 - c. Acceleration: 2 to 60 seconds.
 - d. Deceleration: Zero to 60 seconds.
 - e. Current Limit: 30 to a minimum of 100 percent of maximum rating.
- 9. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:
 - a. Overtemperature.
 - b. Short circuit at controller output.
 - c. Ground fault at controller output. Variable-frequency controller shall be able to start a grounded motor.
 - d. Open circuit at controller output.
 - e. Input undervoltage.
 - f. Input overvoltage.
 - g. Loss of input-phase.
 - h. Reverse phase.
 - i. AC line switching transients.
 - j. Instantaneous overload, line to line or line to ground.
 - k. Sustained overload exceeding 100 percent of controller rated current.
 - l. Starting a rotating motor.
- 10. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
- 11. Automatic Reset and Restart: Capable of [three] restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Controller shall be capable of automatic restart on phase-loss, and overvoltage and undervoltage trips.
- 12. Visual Indication: On face of controller enclosure or chiller control enclosure; indicating the following conditions:
 - a. Power on.
 - b. Run.

- c. Overvoltage.
 - d. Line fault.
 - e. Overcurrent.
 - f. External fault.
 - g. Motor speed (percent).
 - h. Fault or alarm status (code).
 - i. Motor output voltage.
 - j. Input kilovolt amperes.
 - k. Total power factor.
 - l. Input kilowatts.
 - m. Input kilowatt-hours.
 - n. Three-phase input voltage.
 - o. Three-phase output voltage.
 - p. Three-phase input current.
 - q. Three-phase output current.
 - r. Output frequency (Hertz).
 - s. Elapsed operating time (hours).
 - t. Diagnostic and service parameters.
13. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.
14. Harmonic Distortion Filter: Factory mounted and wired to limit total voltage and current distortion to [5] percent.

O. Controls:

- 1. Standalone and microprocessor based with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
- 2. Enclosure: Unit mounted, NEMA 250, [**Type 12**], hinged or lockable; factory wired with a single-point, field-power connection and a separate control circuit.
- 3. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:
 - a. Date and time.
 - b. Operating or alarm status.
 - c. Fault history with not less than last 10 faults displayed.
 - d. Set points of controllable parameters.
 - e. Trend data.
 - f. Operating hours.
 - g. Number of chillers starts.
 - h. Outdoor-air temperature or space temperature if required for chilled-water reset.
 - i. Temperature and pressure of operating set points.
 - j. Entering- and leaving-fluid temperatures of evaporator and condenser.
 - k. Difference in fluid temperatures of evaporator and condenser.
 - l. Fluid flow of evaporator and condenser.
 - m. Fluid pressure drop of evaporator and condenser.
 - n. Refrigerant pressures in evaporator and condenser.
 - o. Refrigerant saturation temperature in evaporator and condenser.
 - p. Pump status.
 - q. Antirecycling timer status.

- r. Percent of maximum motor amperage.
- s. Current-limit set point.
- t. Compressor bearing temperature.
- u. Motor bearing temperature.
- v. Motor winding temperature.
- w. Oil temperature.
- x. Oil discharge pressure.
- y. Phase current.
- z. Percent of motor rated load amperes.
- aa. Phase voltage.
- bb. Demand power (kilowatts).
- cc. Energy use (kilowatt-hours).
- dd. Power factor.

2.3

1. Control Functions:

- a. Manual or automatic startup and shutdown time schedule.
- b. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Evaporator fluid temperature shall be reset based on [return-water] [outdoor-air] [space] temperature.
- c. Current limit and demand limit.
- d. Condenser-fluid temperature.
- e. External chiller emergency stop.
- f. Antirecycling timer.
- g. Variable evaporator flow.
- h. Thermal storage.

2. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:

- a. Low evaporator pressure or temperature; high condenser pressure.
- b. Low evaporator fluid temperature.
- c. Low oil differential pressure.
- d. High or low oil pressure.
- e. High oil temperature.
- f. High compressor-discharge temperature.
- g. Loss of condenser-fluid flow.
- h. Loss of evaporator-fluid flow.
- i. Motor overcurrent.
- j. Motor overvoltage.
- k. Motor undervoltage.
- l. Motor phase reversal.
- m. Motor phase failure.
- n. Sensor- or detection-circuit fault.
- o. Processor communication loss.
- p. Motor controller fault.
- q. Extended compressor surge.

3. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
4. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
5. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
6. Communication Port: RS-232 port or equivalent connection capable of connecting a printer [**and a notebook computer**].
7. Interface with the DDC System for HVAC: Factory-installed hardware and software to enable the DDC system for HVAC to monitor, control, and display chiller status and alarms.

a. Hardwired Points:

- 1) Monitoring: On-off status, [**common trouble alarm**] [**electrical power demand (kilowatts)**] [**electrical power consumption (kilowatt-hours)**] [**power factor**].
- 2) Control: On-off operation, [**chilled-water, discharge temperature set-point adjustment**] [**electrical power demand limit**].

- b. [**ASHRAE 135 (BACnet)**] [**LonTalk**] [**Modbus**] [**Industry-accepted, open-protocol**] communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the DDC system for HVAC.

B. Insulation:

1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C534, Type I for tubular materials and Type II for sheet materials.
2. Thickness: [**1-1/2 inches (38 mm)**].
3. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
4. Factory-applied insulation over cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.
 - a. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
 - b. Seal seams and joints to provide a vapor barrier.
 - c. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

C. Finish:

1. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:

- a. Provide at least one coat of primer with a total dry film thickness of at least **2 mils (0.05 mm)**.
 - b. Provide at least two coats of **[alkyd-modified, vinyl enamel] [epoxy] [polyurethane]** finish with a total dry film thickness of at least **4 mils (0.10 mm)**.
 - c. Paint surfaces that are to be insulated before applying the insulation.
 - d. Paint installed insulation to match adjacent uninsulated surfaces.
 - e. Color of finish coat to be **[custom color selected by Architect]**.
2. Provide Owner with quart container of paint used in application of topcoat to use in touchup applications after Project closeout.

D. Accessories:

1. Flow Switches:

- a. If required and not factory installed, chiller manufacturer shall furnish a switch for each **[evaporator and condenser]** and verify field-mounting location before installation.
- b. Paddle Flow Switches:
 - 1) Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.
 - 2) Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
 - 3) Pressure rating equal to pressure rating of heat exchanger.
 - 4) Construct body and wetted parts of Type 316 stainless steel.
 - 5) House switch in a NEMA 250, **[Type 4]** enclosure constructed of die-cast aluminum.
 - 6) Vane length to suit installation.
- c. Pressure Differential Switches:
 - 1) Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
 - 2) Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.
 - 3) Set Point: Screw type, field adjustable.
 - 4) Electrical Connections: Internally mounted screw-type terminal blocks.
 - 5) Switch Enclosure: NEMA 250, **[Type 4]**.
 - 6) Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.

2. Vibration Isolation:

- a. Chiller manufacturer shall furnish vibration isolation for each chiller.
- b. Neoprene Pad:

- 1) Two layers of **0.375-inch- (10-mm-)** thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
- 2) Fabricate pads from 40- to 50-durometer neoprene.
- 3) Provide stainless-steel square bearing plate to load the pad uniformly between **20 and 40 psig (138 and 276 kPa)** with a **0.12- to 0.16-inch (3- to 4-mm)** deflection.

c. Spring Isolator:

- 1) Stable in operation and designed for not less than 30 percent reserve deflection beyond actual operating conditions. Isolators shall be designed such that the Kx/Ky ratio shall be 1.0 or more for stability.
- 2) Provide PVC or neoprene-coated springs and hot-dip, galvanized-steel components. Aluminum components shall be etched and painted. Nuts, bolts, and washers shall be zinc electroplated.
- 3) Isolators shall be adjustable and with an open spring, having one or more coil springs attached to a top compression plate and a baseplate. An elastomeric pad with a minimum thickness of **0.25 inch (6 mm)** shall be bonded to the baseplate.
- 4) Spring assembly shall be removable and shall fit within a welded steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation. Isolated restraining bolts shall not be engaged during normal operation and shall connect the top plate and lower housing to prevent the isolated equipment from rising when drained of fluid.
- 5) Isolators shall be selected for a nominal [**2-inch (50-mm)**] deflection.

3. Sound Barrier:

- a. Furnish removable and reusable sound-barrier covers over the compressor housing, hermetic motor, compressor suction and discharge piping, and condenser shell.
- b. Provide for repeated installation and removal without use of tape or caulk.
- c. Inner and outer cover shall consist of a PTFE-impregnated fiberglass cloth enclosing heavy-density, needled fiberglass insulation material with a mass-loaded vinyl acoustic barrier.
- d. Covers shall be double sewn and lock stitched with edges folded and sewn so no raw cut edges are exposed.
- e. Form covers around control devices, gages, conduit, piping, and supports without degrading sound-barrier performance.
- f. Continuously lap all exposed seams at least **2 inches (50 mm)** for better sound containment.
- g. Permanently label each section of cover to indicate its location, description, size, and number sequence.
- h. Randomly place stainless-steel quilting pins to prevent covers from shifting and sagging.

4. Tool Kit: Chiller manufacturer shall assemble a tool kit specially designed for use in serving the chiller(s) furnished. Include special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance. Place tools in a lockable case with hinged cover. Provide a list of each tool furnished and attach the list to underside of case cover.

E. Characteristics:

1. Full-Load Efficiency (SEER): <8.7>.
2. Part-Load Efficiency (IPLV): <9.36>.
3. Evaporator:
 - a. Number of Passes: [Three].
 - b. Fluid Type: [Water].
 - c. Entering-Fluid Temperature: <6 (deg C)>.
 - d. Leaving-Fluid Temperature: <12 (deg C)>.
 - e. Fouling Factor: [0.0001 sq. ft. x h x deg F/Btu (0.000018 sq. m x deg C/W)] .
4. Condenser:
 - a. Number of Passes: [Three].
 - b. Fluid Type: [Water].
 - c. Entering-Fluid Temperature: <29 (deg C)>.
 - d. Leaving-Fluid Temperature: <34 (deg C)>.
 - e. Fouling Factor: [0.00025 sq. ft. x h x deg F/Btu (0.000044 sq. m x deg C/W)]
5. Chiller Electrical Requirements:
 - a. Power Factor: [0.95].
 - b. Volts: [380].
 - c. Phase: Three.
 - d. Hertz: 50.
6. Noise Rating: [79] sound power level when measured according to AHRI 575. Provide factory-installed sound treatment if necessary to achieve the required NC level in the adjacent spaces.

2.4 SOURCE QUALITY CONTROL

- A. Perform functional tests of chillers before shipping.
- B. Factory performance test water-cooled chillers, before shipping, according to AHRI 550/590.
 1. Test the following conditions:
 - a. Design conditions indicated.
 - b. Reduction in capacity from design to minimum load in steps of [10] with condenser fluid at design conditions.
 - c. At [10] point(s) of varying part-load performance to be selected by Owner at time of test.
 2. Allow [Owner] access to place where chillers are being tested. Notify Architect [14] days in advance of testing.
 3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
- C. Factory sound test water-cooled chillers, before shipping, according to AHRI 575.
 1. Test the following conditions:

- a. Design conditions indicated.
 - b. Chiller operating at calculated worst-case sound condition.
 - c. At [**five**] point(s) of varying part-load performance to be selected by Owner at time of test.
 2. Allow [**Owner**] access to place where chillers are being tested. Notify Architect [**14**] days in advance of testing.
 3. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
- D. Factory test and inspect evaporator [**and condenser**] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
- E. For chillers located indoors, rate sound power level according to AHRI 575.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine chillers before installation. Reject chillers that are damaged.
- B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.
 1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CHILLER INSTALLATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
- B. Equipment Mounting:
 1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- C. Maintain manufacturer's recommended clearances for service and maintenance.
- D. Charge chiller with refrigerant and fill with oil if not factory installed.
- E. Install separate devices furnished by manufacturer and not factory installed.

3.3 CONNECTIONS

- A. Install piping adjacent to chiller to allow service and maintenance.
- B. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, [**flexible connector,**] flow switch, thermometer, plugged tee with shutoff valve and pressure gage, [**flow meter,**] and drain connection with valve. Make connections to chiller with a [**flange**] [**or**] [**mechanical coupling**].
- C. Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, [**flexible connector,**] flow switch, thermometer, plugged tee with shutoff valve and pressure gage, [**flow meter,**] and drain connection with valve. Make connections to chiller with a [**flange**] [**or**] [**mechanical coupling**].
- D. Refrigerant Pressure Relief Device Connections: For chillers installed indoors, extend [**vent piping**] [**separate vent piping for each chiller**] to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect vent to chiller pressure relief device with flexible connector and dirt leg with drain valve.
- E. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
 - 1. Complete installation and startup check according to manufacturer's written instructions.
 - 2. Verify that refrigerant charge is sufficient and chiller has been leaking tested.
 - 3. Verify that pumps are installed and functional.
 - 4. Verify that thermometers and gages are installed.
 - 5. Operate chiller for run-in period.
 - 6. Check bearing lubrication and oil levels.
 - 7. For chillers installed indoors, verify that refrigerant pressure relief device is vented outdoors.
 - 8. Verify proper motor rotation.
 - 9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
 - 10. Verify and record performance of fluid flow and low-temperature interlocks for evaporator [**and condenser**].
 - 11. Verify and record performance of chiller protection devices.
 - 12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
- B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.
- C. Prepare test and inspection startup reports.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chillers. [**Video record the training sessions.**]

END OF SECTION 236426.16

SECTION 236514.14 - OPEN-CIRCUIT, INDUCED-DRAFT, CROSSFLOW COOLING TOWERS

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 factory-assembled, open-circuit, induced-draft, crossflow cooling towers.

1.3 DEFINITIONS

- A. SCCR: Short-circuit current rating.

1.4 ACTION SUBMITTALS

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

1. Include rated capacities, pressure drop, fan performance data, rating at selected points indicated, and furnished specialties and accessories.
2. Maximum flow rate.
3. Minimum flow rate.
4. Pressure required at cooling tower supply piping connections.
5. Drift loss as percent of design flow rate.
6. Sound:
 - a. Sound pressure levels for operation with fan off, fan at minimum speed, and design speed. If sound requirements are indicated at a specific distance, submit performance using same distance for comparative analysis.
 - b. Sound power levels in eight octave bands for operation with fans off, fans at minimum speed, and design speed.
7. Performance curves for the following:
 - a. Varying entering-water temperatures from design to minimum in [one]-degree temperature increments.
 - b. Varying ambient wet-bulb temperatures from design to minimum in [one] -degree temperature increments.
 - c. Varying water flow rates from design to minimum in increments of [10] percent of flow rate difference between design and minimum flow rates.
 - d. Varying fan operation from design to minimum speed in [10] percent speed increments, and with fan off.

8. Fan airflow at design conditions, brake horsepower, and drive losses (indicated in horsepower and percent of brake horsepower).
9. Fan motor electrical characteristics including, but not limited to, speed, voltage, phase, hertz, amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.
10. Electrical power requirements for each cooling tower component requiring power.

B. Shop Drawings:

1. Manufacturer's drawings of assembled cooling towers, control panels, sections, and elevations.
2. Assembled unit dimensions.
3. Diagram showing each separate piece requiring field assembly.
4. Shipped sub-assembly dimensions and weights for field assembly.
5. Assembled unit weight without water.
6. Operating weight and load distribution.
7. Unit vibration isolation [**and seismic controls**].
8. Required clearances for maintenance and operation.
9. Sizes and dimensioned locations of piping and wiring connections.
10. Diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings:

1. Drawings on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - a. Structural supports.
 - b. Piping roughing-in requirements.
 - c. Conduit and wiring roughing-in requirements for controls and electrical power, including spaces reserved for controls and electrical equipment.
 - d. Access requirements, including working clearances for controls and electrical equipment, and service clearances. Mark and label clearances on drawings.
2. Drawings showing plans, sections, and elevation views, drawn to scale of at least **<1/20 scale>**.
3. Each view to show screened background with the following:
 - a. Structural grids.
 - b. Adjacent walls, floors, and roofs.
 - c. Equipment and products of other trades that are located in vicinity of cooling towers and are part of final installation, such as, controls, power, lighting, fire-suppression systems, and plumbing systems.

B. Seismic Qualification Data: Certificates, for cooling towers, accessories, and components, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Product Certificates: For certification required in "Quality Assurance" Article.
 - D. Field Test Reports: Include startup service reports.
 - E. Source quality-control reports.
 - F. Field quality-control reports.
 - G. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each cooling tower to include in emergency, operation, and maintenance manuals.
- B. Instructional Videos: Including those that are prerecorded and those that are recorded during training.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Belts:
 1. Furnish **[one]** set of matching belts for each unique belt configuration and size furnished.
- B. Tool Kit:
 1. A tool kit specially designed by cooling tower manufacturer for use in servicing cooling tower(s) furnished.
 2. Special tools required to service components not readily available to Owner service personnel in performing routine maintenance.
 3. Lockable case with hinged cover, marked with large and permanent text to indicate the special purpose of tool kit, such as "Cooling Tower Tool Kit." Text size shall be at least **1 inch (25 mm)** high.
 4. A list of each tool furnished. Permanently attach the list to underside of case cover. Text size shall be at least **1/2 inch (13 mm)** high.
- C. Touchup Coating: **[32-oz. (1-L)]** container of paint coating used. Label outside of container with detailed description of coating to allow for procurement of a matching coating in the future.

1.8 QUALITY ASSURANCE

- A. Testing Agency Qualifications: **[Certified by CTI] [An NRTL]**.

- B. CTI Certification: Cooling tower thermal performance according to CTI STD 201RS.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Coordinate requirements for multi-piece assembly for shipment. Limit the number of separate pieces for field installation to as few as possible.
- B. If factory assembly of multiple pieces is required for testing or other reasons, disassemble cooling tower into major assemblies as required by installation before packaging for shipment.
 - 1. Clearly label each separate package with a unique designation and include assembly instructions for complete cooling tower.

1.10 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace the following components of cooling towers that fail in materials or workmanship within specified warranty period:
 - 1. All components of cooling tower.
 - 2. Warranty Period: **[Five]** years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

2.2 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design cooling tower support structure [**and seismic restraints**] [**and wind restraints**], including comprehensive engineering analysis.
- B. Structural Performance: Cooling tower and support structure shall withstand the effects of loads and stresses within limits and under conditions indicated according to [ASCE/SEI 7] [the IBC] [governing codes] .
- C. Seismic Performance: Cooling towers shall withstand the effects of earthquake motions determined according to [ASCE/SEI 7].
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified [**and the unit will be fully operational after the seismic event**]."
 - 2. Component Importance Factor: [1.5].
 - 3. Component Amplification Factor: <as per ASCE/SEI 7>.
 - 4. Component Response Modification Factor: < as per ASCE/SEI 7>.
- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1.

- E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- F. Operation Following Loss of Normal Power:
 - 1. Equipment, associated factory- and field-installed controls, and associated electrical equipment and power supply connected to backup power system shall automatically return equipment and associated controls to the operating state occurring immediately before loss of normal power without need for manual intervention by an operator when power is restored either through a backup power source, or through normal power if restored before backup power is brought on-line.
 - 2. Include means and methods required to satisfy requirement even if not explicitly indicated.
- G. Vibration:
 - 1. Rotating assemblies shall be dynamically balanced to achieve a balance level of "good" while complying with industry-standard requirements for cooling towers.
 - 2. Critical speed shall be at least 115 percent of design speed.

2.3 DESIGN ARRANGEMENT

- A. Crossflow design with airflow from two sides and induced-draft, top-mounted axial fan and gravity distribution basin.

2.4 CASING AND FRAME

- A. Casing Material: **[FRP with UV inhibitors]**.
- B. Frame Material: **[materials to match casing]**.
- C. Hardware: **[stainless]** steel.
- D. Joints and Seams: Sealed watertight.
- E. Welded Connections: Sealed watertight **[by continuous welds]**.

2.5 COLLECTION BASIN

- A. Factory-Assembled Collection Basin:
 - 1. Material: **[FRP with UV inhibitors]**.
 - 2. Hardware: **[stainless]** steel.
 - 3. Joints and Seams: Sealed watertight.
 - 4. Welded Connections: Sealed watertight **[by continuous welds]**.
 - 5. Removable **[stainless-steel]** strainer with openings smaller than nozzle orifices.
 - 6. Overflow and drain connections.
 - 7. Makeup-water connection.
 - 8. Outlet Connection: Configured to mate to ASME B16.5, Class 150 flange.

9. Removable equalization flume plate between adjacent cells of multiple-cell towers.
10. Equalizer connection for field-installed equalizer piping configured to mate to ASME B16.5, Class 150 flange.
11. Basin Sweeper Distribution Piping and Nozzles:
 - a. Pipe Material: **[PVC]** **[or]** **[CPVC]**, Schedule 40 or heavier, treated with UV inhibitors and intended for continuous exposure to direct sunlight with degradation.
 - b. Nozzle Material: **[Plastic]**.
 - c. Configure piping and nozzles to minimize sediment from collecting in the collection basin.
 - d. Basin penetrations sealed watertight.
 - e. Field Connections: Threaded or flanged depending on pipe size.

2.6 COLLECTION BASIN MAKEUP-WATER ASSEMBLY

A. Electric/Electronic, Collection Basin Water-Level Controller with Makeup-Water Valve:

1. Enclosures: NEMA 250, **[Type 4X]**.
2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to **[control makeup-water valve, low- and high-level alarms, and output for shutoff of pump on low level]**.
3. Electrode Probes: Stainless steel.
4. Water Stilling Chamber: **[FRP]**.
5. Makeup-Water Valve:
 - a. Slow closing **[with stainless-steel body]**.
 - b. Actuator controlled and powered through level controller in response to water-level set point.
 - c. Actuator Enclosure: NEMA 250, **[Type 4X]**.
 - d. Fail Position: **[Closed]**.
 - e. Action: **[modulating]**.
6. Electrical Connection Requirements: 220-V ac, single phase, 50 Hz.

2.7 GRAVITY WATER DISTRIBUTION BASIN

- ### A. Design: Non-pressurized design with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated.
1. Material: **[FRP with UV inhibitors]**.
 2. Location: Over each bank of fill with easily replaceable **[plastic]** spray nozzles mounted in bottom of basin.
 3. Inlet Connection: Configured to mate to ASME B16.5, Class 150 flange.
 4. Fasteners: **[stainless]** steel.
 5. Joints and Seams: Sealed watertight.
 6. Welded Connections: Sealed watertight **[by continuous welds]**.

7. Removable Panels: Same material as basin to completely cover top of basin. Secure panels to basin with removable [**stainless-steel**] hardware. Panels reinforced to accommodate service personnel walking on the panels without resulting in permanent deflection and damage.
8. Valves: Manufacturer's standard valve installed at each inlet connection and arranged to balance or shut off flow to each gravity distribution basin.
9. Single-Inlet, Field Pipe Connection: [**PVC**] pipe arranged to achieve balancing of flow within cooling tower cell without the need for additional balancing valves. Pipe each cooling tower cell internally to a single, field connection suitable for mating to ASME B16.5, Class 150 flange and located on the [**bottom**] [**side**] unless otherwise indicated.

2.8 FILL

- A. Materials: PVC, with maximum flame-spread index of [**25**] according to ASTM E84.
- B. Minimum Thickness: [**20 mils (0.5 mm)**] before forming.
- C. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
- D. Fill Material Operating Temperature: Suitable for entering-water temperatures up through [**120 deg F (49 deg C)**].
- E. Hardware: [**stainless**] steel.

2.9 DRIFT ELIMINATORS

- A. Material: [**FRP**]; with maximum flame-spread index of [**25**] according to ASTM E84.
- B. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
- C. Configuration: Multipass, designed and tested to reduce water carryover to [**0.005**] percent of design flow rate indicated.
- D. Location: [**Integral to**] [**Separate and removable from**] fill.
- E. Hardware: [**stainless**] steel.

2.10 AIR INLET

- A. Air-Intake Louvers:
 1. Material: [**Matching casing**]
 2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
 3. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
 4. Location: [**Integral to**] [**Separate from**] fill.

B. **[Removable] Air-Intake Screens:**

1. **[Stainless]**-steel wire mesh with openings of size sufficient to not restrict airflow or impact performance.
2. Segmented into manageable individual sections arranged to facilitate independent removal of each section without disturbing adjoining sections.

C. Hardware: **[stainless]** steel.

2.11 FAN AND DRIVE ASSEMBLY

A. Axial Fan: Balanced at the factory [**after assembly**].

1. Blade Material: **[Aluminum]**.
2. Hub Material: **[Aluminum]**.
3. Blade Pitch: Field adjustable.
4. Fan Shaft: **[Stainless steel]**.
5. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F (minus 29 and plus 149 deg C)**. Bearings designed for an L-10 life of **[100,000]** hours.
6. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

B. Belt Drive:

1. Service Factor: **[1.5]** based on motor nameplate horsepower.
2. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
3. Belt: Multiple V-belt design with a matched set of [**cogged**] belts.
4. Belt: One-piece, multi-grooved, solid-back belt.
5. Belt Material: Oil resistant, non-static conducting, and constructed of neoprene polyester cord.
6. Belt-Drive Guard: Comply with OSHA regulations.

C. Fan Motor:

1. Comply with NEMA MG 1 unless otherwise indicated.
2. Description: NEMA MG 1, **[Design B]**, as required to comply with capacity and torque characteristics; medium induction motor.
3. 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.
4. Motor Enclosure: **[Totally enclosed air-over (TEAO)] [and with epoxy or polyurethane finish]**.
5. Rotor: Random-wound, squirrel cage.
6. Energy Efficiency: **[Comply with ASHRAE/IES 90.1] [NEMA Premium Efficient]**.
7. Service Factor: **[1.15]**.
8. Temperature Rise: **[Match]** insulation rating.
9. Insulation: **[Class F]**.

10. Variable-Speed Motors: Inverter-duty rated per NEMA MG 1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
11. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
12. Severe-Duty Rating:
 - a. Rotor and stator protected with corrosion-inhibiting epoxy resin.
 - b. Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between **minus 20 and plus 300 deg F (minus 29 and plus 149 deg C.)**.
 - c. Complying with IEEE 841.
13. Motor Base: Adjustable, or other suitable provision [**for adjusting belt tension**].
14. Motor Shaft Grounding: Motors shall be controlled through variable-frequency controllers with shaft grounding system to protect motor bearings from induced voltage. Drag on motor shaft due to shaft ground system shall be less than [**0.5**] percent of motor nameplate horsepower.

D. Hardware: [**stainless**] steel.

2.12 AIR DISCHARGE

A. Low-Profile Fan Discharge Stack:

1. Manufacturer's standard low-profile design.
2. Material: [**FRP**].
3. Stack Extension: Fabricated to extend above fan deck **<as per site conditions>** unless otherwise indicated.
4. Stack Termination: Wire-mesh, [**stainless-steel**] screens; segmented into multiple removable pie sections and complying with OSHA regulations.

B. Velocity Recovery Fan Discharge Stack:

1. Design: Tapered and expanded for velocity recovery and improved energy efficiency.
2. Material: FRP or material matching casing.
3. Stack Height: Fabricated to extend above fan deck at least [**5 feet (1.5 m)**] unless otherwise indicated.
4. Service Access: Fabricated of multiple segments to facilitate removal of fan and drive components from overhead.
5. Stack Termination: Wire-mesh, [**stainless-steel**] screens; segmented into multiple removable pie sections and complying with OSHA regulations.

C. Hardware: [**stainless**] steel.

2.13 ELECTRICAL POWER

A. Factory Install: A [**disconnect switch**] [**variable-frequency controller**] for each fan motor.

1. Locate in a convenient and field-accessible location within sight of motor.
2. Installation shall comply with NFPA 70.
3. Wire, Conduit, and Enclosures:
 - a. Minimum Conduit Size: **[0.75 inch (20 mm)]**.
 - b. Materials: Corrosion resistant [**and constructed of stainless steel or PVC coated steel**].
 - c. Motor Termination: Liquidtight conduit, not to exceed **36 inches (900 mm)** long.
 - d. Supports: Support conduits, boxes, and enclosures using corrosion-resistant fastening hardware [**constructed of stainless steel**].
 - e. Wire:
 - 1) Copper, rated for 600-V, solid wire for size [**No. 10 AWG**] and smaller and stranded wire for larger sizes.
 - 2) Minimum Wire Size: [**No. 12 AWG**].
 - 3) Each circuit shall have a ground wire.
 - 4) Install wire in conduit.
 - f. Boxes, Condulets, and Enclosures: NEMA 250, [**Type 4X**].

B. Disconnect Switches:

1. Specification Grade; "Heavy Duty Type"; "quick-make," "quick-break" construction.
2. Three poles, [**fused**].
3. 600 V rated.
4. Minimum SCCR: As required by electrical power distribution system, but not less than **[65,000] A**.
5. Enclosure: NEMA 250, [**Type 4X**].
6. Operating handle shall be of box-mounted type that directly drives switch mechanism.
7. Disconnect switch shall use a flange-operated visible blade that is close coupled to a vertical-lift-type handle that achieves a positive visible indication of disconnect with cover open or closed.
8. Disconnect switch shall have a defeatable, front-accessible, mechanical interlock to prevent opening of cover when switch is in "ON" position, and to prevent turning switch "ON" when the door is open.
9. Include a solid neutral as required by authorities having jurisdiction.
10. Disconnect switch shall have a ground lug for ground wire termination.
11. Operating handle shall be lockable in open position.
12. Horsepower rated.
13. Feed through or double lugged.

C. Variable-Frequency Controllers:

1. Description: NEMA ICS 2; arranged to achieve motor variable speed by adjusting output voltage and frequency.
2. Enclosure: Unit mounted, NEMA 250, [**Type 4X**], with hinged full-front access door with lock and key.
3. Externally Operated [, **Door-Interlocked**] Disconnect: [**Fused disconnect switch**] [**Circuit breaker**] with lockable handle.
4. Minimum SCCR: As required by electrical power distribution system, but not less than **[65,000] A**.

5. Technology: Pulse-width-modulated (PWM) output with insulated gate bipolar transistors (IGBT); suitable for variable torque loads.
6. Controller shall consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.
7. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.
8. Output signal shall be programmed to not cause mechanical vibration issues with fan drive assembly.
9. Operating Requirements:
 - a. Input AC Voltage Tolerance: [10] percent.
 - b. Input frequency tolerance of 50 Hz, plus or minus 2 Hz.
 - c. Capable of driving full motor load, without derating.
 - d. Minimum Efficiency: 96 percent at 50 Hz, full load.
 - e. Minimum Displacement Primary-Side Power Factor: 95 percent.
 - f. Overload Capability: 1.05 times the full-load current for 7 seconds.
 - g. Starting Torque: As required by fan and motor drive assembly.
 - h. Speed Regulation: 1 percent.
 - i. Speed Range: 10:1 speed range.
 - j. To avoid equipment resonant vibrations, include critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
 - k. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.
10. Controller Adjustability Capabilities: Minimum and maximum output frequency, acceleration and deceleration, and current limit.
11. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:
 - a. Overtemperature.
 - b. Short circuit at controller output.
 - c. Ground fault at controller output. Variable-frequency controller shall be able to start a grounded motor.
 - d. Open circuit at controller output.
 - e. Input undervoltage.
 - f. Input overvoltage.
 - g. Loss of input phase.
 - h. Reverse phase.
 - i. AC line switching transients.
 - j. Instantaneous overload, line to line or line to ground.
 - k. Sustained overload exceeding 100 percent of controller rated current.
 - l. Starting a rotating motor.
12. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
13. Automatic Reset and Restart:
 - a. Capable of multiple restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction.
 - b. Capable of automatic restart on phase-loss and overvoltage and undervoltage trips.

14. Visual Indication: On face of controller; indicating the following conditions:
 - a. Power on.
 - b. Run.
 - c. Overcurrent and overvoltage.
 - d. Motor speed (percent).
 - e. Various faults with alarm status.
 - f. Input kilovolt amperes.
 - g. Power factor.
 - h. Input kilowatts and kilowatt-hours.
 - i. Three-phase input and output voltage.
 - j. Three-phase input and output current.
 - k. Output frequency.
 - l. Elapsed operating time (hours).
 - m. Diagnostic and service parameters.
15. Operator Interface: Start-stop and auto-manual selector with manual-speed-control potentiometer.
16. Control Signal Interface: A minimum of **[four]** analog inputs (0 to 10 V or 0/4 to 20 mA) and **[four]** programmable digital inputs.
17. Bypass Controller:
 - a. Integrated NEMA ICS 2, Class A, full-voltage, non-reversing, motor-rated controller to operate fan motor if variable-frequency controller is not operational.
 - b. Configure power supply to bypass controller and variable-frequency controller to completely isolate power to variable-frequency controller while operating fan motor through bypass controller for safe servicing of variable-frequency controller.
 - c. Include "Bypass/VFC" manual selector switch on face of enclosure for local operator control of preferred controller.
 - d. Include fail-safe control logic to automatically transfer fan motor operation from failed variable-frequency controller to bypass controller.
 - e. Install bypass controller in same enclosure as variable-frequency controller.

2.14 CONTROLS

A. Vibration Switch: For each fan drive.

1. Enclosure: NEMA 250, **[Type 4X]**.
2. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
3. Switch shall have manual-reset button hardwired connection to fan motor electrical circuit.
4. Switch shall have field connection to a control system hardwired connection to fan motor electrical circuit.
5. Switch shall, on sensing excessive vibration, **[signal an alarm for connection to control system and]** shut down the fan.

B. Vibration Transmitter with Switch: For each fan drive.

1. Enclosure: NEMA 250, Type 4X.
2. Display: Local display of measured value, power, and alarm.
3. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point.
 - a. Cooling tower manufacturer shall select range that is suitable for cooling tower and recommend switch set point for proper operation and protection.
4. Transmitter: Continuous vibration level indication through a 4- to 20-mA signal for connection to control system.
5. Switch:
 - a. Relay and switch with manual-reset button for field connection to control system and hardwired connection to fan motor electrical circuit.
 - b. Switch shall, on sensing excessive vibration, signal an alarm to control system and shut down the fan.
6. Mounting: Locate out of cooling tower discharge airstream and mount in a location that is accessible [**and where display is easily viewable**].
7. Field Electrical Connection Requirements: 220 V, single phase, 50 Hz.

C. Control Package:

1. Factory installed and wired, and functionally tested at factory before shipment.
2. NEMA 250, [Type 4X] enclosure with removable internally mount backplate.
3. Control-circuit transformer with primary and secondary side fuses.
4. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
5. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
6. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
7. Collection basin level controller complying with requirements in ["**Electric/Electronic, Collection Basin Water-Level Controller with Makeup-Water Valve**"] Paragraph in "Collection Basin Makeup-Water Assembly" Article.
8. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
9. Single-point, field-power connection to a [fused disconnect switch] [circuit breaker] [**for each cooling tower cell**].
 - a. Branch power circuit to each motor and electric basin heater and to controls [**with a disconnect switch or circuit breaker**].
 - b. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Include variable-frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
10. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquid tight conduit.
11. Visual indication of status and alarm [**with momentary test push button**] for each motor.
12. Audible alarm and silence switch.

13. Visual indication of elapsed run time, graduated in hours for each motor.
14. Cooling tower shall have hardware to enable control system to remotely monitor and display the following:
 - a. Operational status of each motor.
 - b. Cooling tower leaving-fluid temperature.
 - c. Fan vibration alarm.

2.15 SERVICE ACCESS

A. Doors:

1. Large enough for personnel to access cooling tower internal components from both cooling tower end walls.
2. Doors shall be hinged with handles operable from both sides of the door.
3. Door materials shall match casing.
4. Hinges and handles shall be [**stainless steel**].

B. External Ladders with Safety Cages: [**FRP**] fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.

C. External Platforms with Handrails: [**FRP**] bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.

D. External Motor Platforms with Handrails: [**FRP**] bar grating.

E. Fan Deck Floor between Cooling Tower Cells:

1. Factory furnish reinforced fan deck floor panels between cooling tower cells for field installation.
2. Floor materials shall match adjacent cooling tower cell fan deck.
3. Fan deck floor shall fasten to and be supported by framing that is attached to cooling tower cells.
4. Frame shall be constructed of same materials as cooling tower frame.

F. Handrail: [**FRP**] complete with kneerail and toeboard, around external platforms and top of cooling tower. Comply with 29 CFR 1910.23.

G. Internal Platforms: [**FRP**] bar grating.

1. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high-water level of the collection basin.
2. Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

H. Hardware: Galvanized steel when connecting galvanized-steel components; stainless steel when connecting other materials.

2.16 CAPACITIES AND CHARACTERISTICS

- A. Air-Inlet Arrangement: [**Two sides**].
- B. Maximum Drift Loss: [**0.005**] percent of design water flow.
- C. Fan Drive Assembly:
 - 1. Type: [**Belt**].
 - 2. Fan Motor:
 - a. Type: [**Variable speed**].
 - b. Electrical Characteristics: [**380**] -V ac, 3 phase, 50 Hz.
- D. Sound Pressure Level: <**low noise suitable for Presidential Palace application**> [**when measured according to CTI ATC 128**].

2.17 SOURCE QUALITY CONTROL

- A. Performance Test: Factory test and certify cooling tower performance according to CTI STD 201RS, "Standard for the Certification of Water-Cooling Tower Thermal Performance."
 - 1. Allow [**Owner**] access to place where cooling towers are being tested. Notify Owner in writing at least [**30**] days in advance of testing.
 - 2. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
- B. Seismic Performance Testing: Shake table tested by an independent [**or a factory-certified**] **laboratory** to certify performance complies with seismic requirements indicated.
 - 1. Allow [**Owner**] access to place where cooling towers are being tested. Notify Owner in writing at least [**30**] days in advance of testing.
 - 2. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
- C. Factory Functional Tests:
 - 1. Test collection and distribution basins after assembly, and prove free of leaks.
 - 2. Test factory-installed electric/electronic water-level controls for proper operation.
 - 3. Test factory-installed electric basin heaters for proper operation.
 - 4. Test factory-installed fan and drive assemblies for proper operation.
 - 5. Test factory-installed control package for proper operation.
 - 6. Test access doors to ensure smooth operation and proper fit.
 - 7. Allow [**Owner**] access to place where cooling towers are being tested. Notify Owner in writing at least [**30**] days in advance of testing.
 - 8. Submit report documenting tests performed and results within one week of test date.
- D. Owner Travel Expenses:

1. Include cost associated with Owner travel expenses to witness testing. Total value attributed to travel expenses shall be clearly indicated.
2. Expenses shall include round-trip coach airfare, out of town hotel accommodations, out of town meals (breakfast, lunch, and dinner), out of town ground transportation, and all associated taxes and fees.
3. Exclude other incidental expenses not indicated.
4. Include travel expenses for [**two**] Owner representative(s).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine cooling towers before installation. Reject cooling towers that are damaged.
- B. Before cooling tower installation, examine roughing-in for tower support, anchor-bolt sizes and locations, piping, controls, and electrical connections to verify actual locations, sizes, and other conditions affecting cooling tower performance, maintenance, and operation.
 1. Cooling tower locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping, controls, and electrical connections.
 2. Verify sizes and locations of concrete bases and support structure with actual equipment.
 3. Verify sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting:
 1. Install cooling towers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
 2. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 3. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- B. Install anchor bolts to elevations required for proper attachment to supported equipment.
- C. Maintain manufacturer's recommended clearances for service and maintenance.
- D. Maintain clearances required by governing code.
- E. Loose Components: Install components, devices and accessories furnished by manufacturer, with cooling tower, that are not factory mounted.
 1. Loose components shall be installed by [**Contractor under supervision of manufacturer's factory-trained service personnel**].

3.3 PIPING CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to cooling towers, allow space for service and maintenance.
- C. Install flexible pipe connectors at pipe connections of cooling towers mounted on vibration isolators.
- D. Install drain piping with valve at cooling tower drain connections and at low points in piping.
- E. Connect cooling tower overflows and drains, and piping drains, to sanitary sewage system.
- F. Makeup-Water Piping:
 - 1. Comply with applicable requirements in Section 221116 "Domestic Water Piping."
 - 2. Connect to makeup-water connections with shutoff valve, plugged tee with pressure gage, flow meter, and drain connection with valve and union.
- G. Supply and Return Piping:
 - 1. Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."
 - 2. Connect to entering cooling tower connections with shutoff valve, strainer, balancing valve, thermometer, plugged tee with pressure gage, flow meter, and drain connection with valve.
 - 3. Connect to leaving cooling tower connection with shutoff valve thermometer, plugged tee with full port ball valve for portable field instruments, and drain connection with valve.
 - 4. Make connections to cooling tower with a flange.
- H. Equalizer Piping:
 - 1. Piping requirements to match supply and return piping.
 - 2. Connect an equalizer pipe, full size of cooling tower connection, between tower cells.
 - 3. Connect to cooling tower with shutoff valve and drain connection with valve.
 - 4. Make connections to cooling tower with a flange.
- I. Basin Sweeper Piping:
 - 1. Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties."
 - 2. Connect to supply connections with shutoff valve [, **flow meter**,] and drain connection with valve.
 - 3. Connect to return connections with shutoff valve, balancing valve, [, **flow meter**,] and drain connection with valve.
 - 4. Make connections with a [**flange**] [**or**] [**union**].

3.4 ELECTRICAL POWER CONNECTIONS

- A. Connect field electrical power source to each separate electrical device requiring field electrical power. Coordinate termination point and connection type with Installer.
- B. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for wiring connections.
- C. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems" for grounding connections.
- D. Install nameplate for each electrical connection indicating electrical equipment designation and circuit number feeding connection. Nameplate shall be laminated phenolic layers of black with engraved white letters at least **1/2 inch (13 mm)** high. Locate nameplate where easily visible.

3.5 CONTROLS CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring between cooling towers and other equipment to interlock operation as required to achieve a complete and functioning system.
- C. Connect control wiring between cooling tower control interface and control system for HVAC for remote monitoring and control of cooling towers. Comply with requirements in **[Section 230923 "Direct Digital Control (DDC) System for HVAC"]**.
- D. Install label at each termination indicating control equipment designation serving cooling tower and the I/O point designation for each control connection. Comply with requirements in Section 260553 "Identification for Electrical Systems" for labeling and identifying products and installations.

3.6 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Tests and Inspections: Comply with **[ASME PTC 23] [CTI ATC 105]**.
- D. Cooling towers will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.7 STARTUP SERVICE

- A. **[Engage a factory-authorized service representative to perform]** startup service.
- B. Inspect field-assembled components, equipment installation, and piping; controls; and electrical connections for proper assemblies, installations, and connections.
- C. Obtain performance data from manufacturer.
 - 1. Complete installation and startup check according to manufacturer's written instructions and perform the following:
 - a. Clean entire unit including basins.
 - b. Verify that accessories are properly installed.
 - c. Verify clearances for airflow and for cooling tower servicing.
 - d. Check for vibration isolation and structural support.
 - e. Lubricate bearings.
 - f. Verify fan rotation for correct direction and for vibration or binding and correct problems.
 - g. Adjust belts to proper alignment and tension.
 - h. Operate variable-speed fans through entire operating range and check for harmonic vibration imbalance. Set motor controller to skip speeds resulting in abnormal vibration.
 - i. Check vibration switch setting. Verify operation.
 - j. Verify water level in tower basin. Fill to proper startup level. Check makeup-water-level control and valve.
 - k. Verify that cooling tower air discharge is not recirculating air into tower or HVAC air intakes. Recommend corrective action.
 - l. Replace defective and malfunctioning units.
- D. Start cooling tower and associated water pumps. Follow manufacturer's written starting procedures.
- E. Prepare a written startup report that records the results of tests and inspections.

3.8 ADJUSTING

- A. Set and balance water flow to each tower inlet.
- B. Adjust water-level control for proper operating level.

3.9 DEMONSTRATION

- A. **[Engage a factory-authorized service representative to train]** Owner's maintenance personnel to adjust, operate, and maintain cooling towers.
1. Video record the training sessions.
 2. Instructor shall be factory trained and certified.
 3. Perform not less than **[8]** hours of training.
 4. Train personnel in operation and maintenance and to obtain maximum efficiency in plant operation.
 5. Perform instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.
 6. Obtain Owner sign-off that training is complete.
 7. Owner training shall be held at Project site.

END OF SECTION 236514.14

SECTION 255000 – INTEGRATED AUTOMATION FACILITY CONTROLS

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.
- B. Related Documents
 - 1. The latest Edition of the following standards and codes in effect and amended as of supplier's proposal date, and any applicable subsections thereof, shall govern design and selection of equipment and material supplied:
 - a. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
 - b. ANSI/ASHRAE Standard 135-1995, BACnet.
 - c. Uniform Building Code (UBC), including local amendments.
 - d. UL 916 Underwriters Laboratories Standard for Energy Management Equipment. Canada and the US or equivalent.
 - e. National Electrical Code (NEC).
 - f. FCC Part 15, Subpart J.
 - g. EMC Directive 89/336/EEC.
 - h. KNX/EIB Standard EN 50090, ISO/IEC 14543.
 - i. City, country, state, and federal regulations and codes in effect as of contract date.

1.2 SUMMARY

- A. Work Includes:
 - 1. A fully integrated Building Automation and Control System (BACS), UL listed, incorporating direct digital control technology, equipment monitoring and control including colour graphic workstations. System major elements include, without being limited to, the following:
 - a. Computer based processing units.
 - b. Personal computer operator workstations.
 - c. Data storage units.
 - d. Stand alone Data terminal units.
 - e. Data communication units.
 - f. Stand alone Remote control units.
 - g. Portable operator's terminals.
 - h. Data interface units.
 - i. Communication cable.
 - j. System software.
- B. Related Work
 - 1. The following divisions contain requirements that relate to this section:
 - a. Division 23 Mechanical
 - b. Division 25, 26, 27,28 Electrical

C. Scope of Work

1. General: all materials and/or equipment, necessary for proper operation of the systems, not specified or described herein are to be deemed part of the Specification. Perform the work under this section and provide all labour, materials, services, equipment and accessories necessary to furnish and install all instrumentation and equipment as indicated by the Drawings and/or as required by the Specification, which without limiting the generality thereof, consists of the following:
 - a. Master Control Communication Station: to be located in the central control room where shown on the Drawings and to be the primary operator's position for the systems being monitored and controlled. From this position the operator is to monitor and control all systems of the building (pumps, ventilation control, etc..) via a communication network at a minimum of 76.8 Kbaud communication speed.
 - b. Field Processing Unit (FPU): to monitor and control all functions specified on the function list. Field Procession Units or controllers (FPU) are to be of the pre-programmed and/or programmable type of appropriate number of input/output points for the specified application.
 - c. Interfacing Panels to enable connection to physical control points via transducers, signal conditions, interposing relays and the like.
 - d. Instrumentation, including sensors/transducers, transformers, sensing piping, tubing as required.
 - e. Field wiring conducting communication trunks from DDC/FPU back to central processors in addition to interconnections between processors peripherals, etc. to yield a complete system. This to include power supply connection from nearest emergency panels/substations.
 - f. Shop drawings, as-built drawings, instruction manuals, source code programme listing and all other documentation as required.
 - g. Testing and commissioning of installations to take over.
 - h. Data points shall be available in plant rooms to hook up laptop within the same for monitoring and control. All latest software, devices and accessories shall be incorporated.
 - i. IP backbone with a minimum speed of 1 GBPS shall be provided for BMS integration & communication.
 - j. UPS power shall be made available for all DDC/FPU's & network components.
 - k. Along with drawings software, licenses & Interfaces shall also be provided.

D. System Description

1. Building Automation and Control System: Distributed process control system consisting of central control, central communications, and remote-control systems to monitor and control the following building systems:
 - a. Air Conditioning Systems control.
 - b. Energy Management
 - c. Power supply
 - d. PMU's/BTU meters through BACnet/mod Bus
2. The communication method between the different components of the BACS system (DDCs & Third-party Gateways) shall use the "BACNET" Building Automation and Control Networking Protocol as per ASHRAE Standard 135-95. All systems shall be compatible with the above standard protocol as applicable.
3. General Product Description:
 - a. The Building Automation and Control System (BACS) shall integrate multiple building functions including equipment supervision and control, alarm management, energy management and historical data collection.
 - b. The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, field processing units (FPU's), Application Specific Controllers and operator devices.
 - c. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each FPU shall operate independently by performing its own specified control, alarm management, operator I/O and data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.
 - d. FPU's shall be able to access any data from, or send control commands and alarm reports directly to, any other FPU or combination of FPU's on the network without dependence upon a central processing device. FPU's shall also be able to send alarm reports to multiple operator workstations without dependence upon a central processing device.

E. Schedule of Control Functions

1. Schedule of control functions included in the Drawings or in this Specification is for the control and monitoring functions related to HVAC, Plumbing and Electrical Works.

F. Design Requirements

1. Design central processing unit with modular system architecture to allow expansion of processor memory and addition of application software programs, terminal units, and central memory units.
2. Minimum System Configuration: Accommodate input and output points, building systems data base, and functions specified and allow for 20% additional input/output points and related expanded data base, without modifying system hardware or software.

3. Future System Expansion: Design system to be expanded to accommodate 50% additional input/output points and related expanded data base, without modifying system hardware or software. Design application software programs and system database to be transportable to expanded central processing unit if required to accommodate specified future expansion.
4. Operator Data Terminal Unit: Provide operator interface functions through data terminal unit, including manual setpoints and overrides, data base display and maintenance, program loading and entry, operating system software functions, alarm display and acknowledge, graphic display, and operation logging.
5. Design operator display terminal data screens with the following features:
 - a. Split screen display to allow entering commands and variables while observing status and alarm screen.
 - b. Provide constant display of date, time, outside environmental conditions, and system status.
 - c. Indicate off-normal conditions in a flashing display.
6. Design graphic display screens to present dynamic, interactive display of process variables and system status.
7. Layout data terminal units to allow operator to view displays, acknowledge system alarms and messages, manually enter data or commands, and communicate over telephone or intercom systems from one seated position.
8. Central Control System: Perform the following functions:
 - a. Perform optimisation routine.
 - b. Display value of each input point.
 - c. Display alarm when value of any input point exceeds preset minimum or maximum limit.
 - d. Record each alarm indication.
 - e. Record each operator-initiated action of control system.
9. Design central communication system to control input and output between central processing unit, data memory units, remote control units, and data gathering units.
 - a. Data Communication Network: Single distributed control network.
 - b. Network Topology: Ring
 - c. Network Media: Twisted pair
 - d. Network Protocol: Deterministic arbitration using token passing, master/slave arrangement.
 - e. Network Transmission Speed: Minimum 76.8 Kbaud.
10. Remote Control System: provide the following functions and features:
 - a. Signal inputs
 - b. Control outputs
 - c. Data and program memory
 - d. Independent control and monitoring of local processes during failure of central control or central communication systems.

11. Design and build all system components to be fault-tolerant.
 - a. Satisfactory operation without damage at 110% and 85% of rated voltage and at plus 3 Hertz variation in line frequency
 - b. Static, transient and short-circuit protection on all inputs and outputs
 - c. Protect communication lines against incorrect wiring, static transients and induced magnetic interference
 - d. Network-connected devices to be A.C. coupled or equivalent so that any single device failure will not disrupt or halt network communication.
 - e. all real time clocks and data file RAM to be battery-backed for a minimum 72 hours and include local and system low battery indication.
 - f. It must be possible to receive and print out alarms at a central location even when the workstation at that location is non-operational or taken out of service for periodic maintenance.
12. Design system to continue operation of alarm display and printing at central location and operation of remote-control unit functions during removal or failure of central processing unit.

G. Qualifications

1. Manufacturer and installer to have an office staffed with factory trained engineers and technicians fully capable of providing instructions, routine maintenance and emergency maintenance service on all system components.
2. Manufacturer and installer to have at least 7 years experience in design and installation of computerized building systems similar to performance to that specified herein and to provide evidence of experience as condition of acceptance and approval.
3. Supplier to have an in-place support facility within 100 km of the site with spare parts inventory and all necessary test and diagnostic equipment.

H. Quality Assurance

1. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Section 15, Governing Radio Frequency Electromagnetic Interference and be so labeled.
2. BACS shall comply with UL 916 PAZX and 864 UDTZ and be so listed at the time of bid. All equipment used in system is to bear appropriate UL listing label/mark to ensure compliance.
3. Systems conforming to other equivalent international regulatory requirements will be accepted. The burden of proof for equivalent is on the Contractor.

I. Submittals

1. Submit in accordance with the Contract Documents.
2. Shop Drawings: Indicate system configuration; interconnection wiring diagrams; location, data characteristics, range and units for each input and output point; logic diagram for each type of control routine; programming and operating reference for processing unit operating system; programming and operating reference for each application and programming language provided.

3. Product Data: Provide for each component, including sensors, control drives and elements, plug-in circuit boards, and enclosed equipment units. Include cabinet dimensions, weights, and support point locations for each item of enclosed equipment.
4. Design Data: Indicate basis of optimisation algorithms.
5. Manufacturer's Installation Instructions: Indicate installation instructions.
6. Submit software provider's license agreement stating limits on use, copying, and transferring software.
8. Manufacturer's Field Reports: Indicate acceptance of component and equipment installation, interconnecting wiring, and weekly progress on installation and start-up of system software.
9. Where installation procedures, or any part thereof, are required to be in accordance with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be furnished to the Engineer prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received.
10. P & I or process flow diagrams: to be completed for each system and submitted for approval.
11. Technical Data Sheets: control and instrumentation technical data sheets (TDS) to be prepared for each advice.
12. Loop Diagrams: control and instrument loop diagrams prepared and furnished for all instrument systems. Typical diagrams are not permitted. Loop diagrams are to be unique for each loop.
13. Equipment Installation Plans: to indicate location of instrument junction boxes, individual field instruments, transmitter racks, and routing of cable duct from junction boxes to respective remote processing units and back to Central Control Room. This is to be accompanied by a list of control points connected by each FPU, with indication of related control functions. Interfacing provided is to be listed; these are to be grouped as per standard sub-module size of Digital and Analog input/output boards, comprising similar requirements; such as interposing relays amplifiers, level translators, etc..
14. Operating Consoles: drawings detailing operating consoles, instrument panel layouts and dimensions and control room plans.
15. Instrument Installation: detail drawings for each field installation are to be furnished. Details are to include but are not limited to instrument piping details, transmitter rack details and pipe mounted equipment installation details.
16. Logic Diagrams detailing the operational logic are to be completed for the digital binary operations. In addition to these drawings, operational logic descriptions are to be prepared detailing the sequence of operation and operational constraints and limitations.

17. Instrument schedule listing all devices to be keyed to instrument loop number and device numbers.
18. Instrument Schedule to provide a comprehensive data source indicating where all specific information may be found for each service. Schedule to include not only balance of plant equipment but also that equipment furnished as part of packaged systems and is to be noted as such.
19. Prior to procurement of equipment submit for approval the following drawings and documents:
 - a. Process and instrumentation flow diagrams.
 - b. Equipment Specifications and completed technical data sheets.
 - c. Control logic diagrams and logic descriptions.
 - d. Input/output points charts for every processing unit.
20. Prior to start of system installation and construction submit for approval the following drawings and documents:
 - a. Shop drawings for valves, dampers, transducers, transmitters, signal conditioners, indicators, recorders, miscellaneous instruments, central operator processing unit, consoles and ancillary.
 - b. Control loop diagrams.
 - c. Electrical elementary diagrams.
 - d. Instrument installation plans.
 - e. Detailed panel diagrams.
 - f. Point to point wiring diagrams.
 - g. Instrument schedule, including processing unit panel termination/interface.
21. Prior to commencing start-up activities, the following documents to be submitted for approval:
 - a. System construction inspection procedures.
 - b. Points calibration procedures.
 - c. Calibrated control checkout procedures.
 - d. Plant operational system test procedures.
 - e. Operator and maintenance personnel training curriculum.
22. Prior to system acceptance and turnover and as a condition of system acceptance, the following documents are to be submitted in four copies in accordance with contract requirements.
 - a. System user manual.
 - b. Systems maintenance manual including Specifications of each piece of equipment, trouble-shooting charts, and preventing maintenance instructions, technical data sheet for each instrument referenced for each application.
 - c. As-built drawings including equipment outlined dimension drawings, equipment wiring and or piping connection drawing.

- d. Complete supplementary information about software and hardware of system supplied. This to include:
 - 1) System block diagram (hardware)
 - 2) Software “functional” flow diagram
 - 3) Memory map of all units
 - 4) Specific tasks performed by each processor, especially where a distributed processing architecture is provided. These are to be clearly indicated in functional form.
 - 5) Source and object lists of software program
- e. Point schedule.
- f. Panel wiring drawing.
- g. Control schematics.
- h. System architecture.
- i. Control strategies.

J. Delivery, Storage and Handling

- 1. Deliver, store, protect and handle products to site under provisions of the Contract Documents.
- 2. Accept products on site and verify damage.
- 3. Protect products from construction operations, dust and debris by storing in conditioned space.

K. Maintenance Service

- 1. Furnish service and maintenance of building management system for one year from Date of Substantial Completion.
- 2. Include installation of software revisions issued during maintenance service period.

L. Spare Parts

- 1. As soon as practicable after approval of materials and equipment and, if possible, not later than 4 months prior to the date of beneficial use, submit spare parts data for each different item of equipment furnished. Data to include a complete source of supply, a list of parts and supplies that are either normally furnished at no extra cost with the purchase of the equipment, or specified hereinafter as EXTRA MATERIALS to be furnished as part of the Contract; and a list of additional items recommended by the manufacturer to assure efficient operation for a period of 360 days at the particular installation. The foregoing is not to relieve the Contractor of any responsibilities under the guarantee condition.

M. Extra Materials

- 1. Provide special tools required for maintenance.
- 2. Provide two of each plug-in circuit board.
- 3. Provide 1000 sheets of continuous form paper.

PART 2 - PRODUCTS

2.1 APPROVED MANUFACTURERS

- A. Unless specifically mentioned otherwise, all controls and instruments specified shall be from internationally known manufacturers specialized in controls and having not less than 30 years of active production in controls.

2.2 NETWORKING COMMUNICATIONS

- A. The design of the BACS shall network operator workstations and stand-alone FPU's in a peer-to-peer BACnet design scheme.
- B. Access to system data shall not be restricted by the hardware configuration of the Building Management System. The hardware configuration of the BACS network shall be totally transparent to the user when accessing data or developing control programs.
 - 1. Operator workstations and FPU's shall directly reside on a network such that communications may be executed directly between FPU's, directly between workstations and between FPU's and workstations.
 - 2. Network design shall include the following provisions:
 - a. Provide high-speed data transfer rates for alarm reporting, quick report generation from multiple controllers and upload/download efficiency between network devices. System performance shall insure that an alarm occurring at any FPU is displayed at workstations and/or alarm printers within 5 seconds.
 - b. Support of any combination of FPU's and operator workstations directly connected to the network.
 - c. Message and alarm buffering to prevent information from being lost.
 - d. Error detection, correction and retransmission to guarantee data integrity.
 - e. Synchronization of real-time clocks.
- C. Telecommunication Capability:
 - 1. Auto-dial/auto-answer communications shall be provided to allow FPU's to communicate with remote operator stations and/or remote terminals on an intermittent basis via telephone lines, as indicated in the sequence of operations.
 - 2. Provide all necessary hardware and software for remote communications with all remote processors, back-up processors and all operator input/output peripheral devices.

2.3 CENTRAL PROCESSING

- A. BACS hardware to be totally solid-state using computer oriented digital technology. System to have a fully modular architecture permitting expansion by adding computer memory, additional processing units application software, operator peripherals and field hardware.

- B. Main Station Processing Unit to be Workstation: IBM-compatible microcomputer with configuration LATEST available during installation.
1. Processor
 2. Random-Access Memory
 3. Cache Memory:
 4. Graphics: Super video graphic adapter (SVGA)
 5. Monitor: 21 inches, LCD
 6. Keyboard: QWERTY, 105 keys in ergonomic shape
 7. Hard-Disk Drive
 8. DVD- Drive
 9. Mouse
 10. Modem
 11. Operating System
 12. BACnet Conformance: Workstation shall support BACnet device and have minimum capabilities defined in PICS for the following areas:
 - a. Network.
 - b. Functional groups.
 - c. Standard application services supported.
 - d. Standard objects supported.
- C. Field Processing Unit or Controller to be distributed stand-alone for control of various unitary and terminal equipment or controls with built in network communication for integration into the BACS system.
- D. Loading/Backup Facilities: provide as an integral of an IBM PC or compatible, all hardware required to load, reload, or backup the memory of the system and the software to execute specified functions. Loading of system to be through use of high-speed, mass storage media, such as magnetic tape cartridge or floppy diskette. This same media to be used for making on-line system backups and for remote historical data storage.
- E. Data Dumping: if FPU memory fails, the operator shall not have to manually re-enter system data. Necessary hardware and software are to be supplied to:
1. Allow periodic dumping of operator-entered data onto another storage media on line.
 2. Reload this data as the operator desires.
 3. Data dumping are not to interrupt any other system operation (such as operator input/output, scanning of field hardware, application software execution, etc...).
- D. A user-friendly programming language is to be used to programme the FPU and the zone controller connected to it. Further the panel is to have the predefined software listed below:
1. Input points
 2. Output points
 3. Pulse points
 4. Annual schedule
 5. Weekly schedule
 6. Daily schedule
 7. Alarm
 8. Controller
 9. Totalizer
 10. Trend log
 11. Zone controller access points
 12. Optimised start

- 13. System display
- 14. User access
- 15. Scale range
- 16. Load shed

2.4 FPU/DDC CONTROLLERS

- A. Stand-alone Controllers shall be microprocessor Native BACnet Protocol based with a minimum word size of 16 bits. They shall also be multi-tasking, multi-user, real-time, digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size shall be sufficient to fully meet the requirements of this Specification and the attached function list.
- B. Each FPU shall have sufficient memory, a minimum of 16 megabyte, to support its own operating system and database.
- C. Each FPU shall have a minimum of 30% spare capacity for future point connection. The type of spares shall be in the same proportion as the implemented I/O functions of the panel, but in no case shall there be less than two spares of each implemented I/O type. 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.
 - 1. Provide sufficient internal memory for the specified control sequences and have at least 30% of the memory available for future use.
- D. FPU shall provide at least two RS-232C serial data communication ports for operation of operator I/O devices such as industry standard printers, operator terminals, modems and potable operator's terminals. FPUs shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers and terminals.
- E. FPUs shall provide local LED status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Graduated intensity LEDs or Analog indication of value shall be provided for each Analog output. Status indication shall be visible without opening the panel door.
- F. Each FPU shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components.
- G. In the event of the loss of normal power non-volatile memory shall be incorporated for all critical controller configuration data and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
 - 1. Upon restoration of normal power, the Controller shall automatically resume full operation without manual intervention.

2.5 FPU/DDC RESIDENT SOFTWARE FEATURES

A. General:

1. All necessary software to form a complete operating system as described in this specification shall be provided.
2. The software programs specified in this Section shall be provided as an integral part of FPU/DDC Controllers and shall not be dependent upon any higher level computer for execution.
3. Control Software Description:
 - a. The DDC Controllers shall have the ability to perform the following pre-tested control algorithms:
 - 1) Two-position control
 - 2) Proportional control
 - 3) Proportional plus integral control
 - 4) Proportional, integral, plus derivative control
 - 5) Control loop tuning
 - b. Control software shall include a provision for limiting the number of times each piece of equipment may be cycled within any one-hour period.
 - c. The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.
 - d. Upon the resumption of normal power, each FPU/DDC Controller shall analyse the status of all controlled equipment, compare it with normal occupancy scheduling and turn equipment on or off as necessary to resume normal operations.
4. DDC Controllers shall have the ability to perform any or all the following energy management routines:
 - a. Time-of-day scheduling
 - b. Calendar-based scheduling
 - c. Holiday scheduling
 - d. Temporary schedule overrides
 - e. Start-Stop Time Optimisation
 - f. Automatic Daylight Savings Time Switchover
 - g. Night setback control
 - h. Enthalpy Switchover (economizer)
 - i. Peak Demand Limiting
 - j. Temperature-compensated duty cycling
 - k. Fan speed/CFM control
 - l. Heating/cooling interlock
 - m. Cold deck reset
 - n. Hot deck reset
 - o. Hot water reset
 - p. Chilled water reset
 - q. Chiller sequencing

2.6 PORTABLE OPERATOR'S TERMINAL (POT)

- A. Provide one portable operator terminal with a minimum LCD display of 80 characters by 25 lines and a full-featured keyboard. The POT shall be handheld and plug directly into individual distributed control panels. Provide a user friendly, English language prompted interface for quick access to system information, not codes requiring look-up charts.
- B. If the same Portable Operator's Terminal cannot be used for all control processors, provide separate POTs to accomplish the above functional requirements.
- C. Portable operator terminal access to controller shall be password controlled.

2.7 OPERATOR PERIPHERAL DEVICES

- A. General: operator peripheral device communications, here designated as Man-Machine Interface (MMI) to be handled simultaneously through various devices generally categorized as software and hardware. Each device may be connected in a direct proprietary, leased phone line, or dial-up phone line application.
- B. Standards: all peripheral devices to utilize ASCII (American Standard Code for Information Interchange) code and to be interfaced to the processing units with standard RS 232 port. Communication versatility is to comply with all methods previously specified herein.
- C. Operator Station to comprise multiple operator peripheral input/output devices which can all be used simultaneously.
- D. Operator Access to system to be restricted by a software coding process. Systems which provide only manual key lock accessibility are not acceptable.
- E. Printers: system printers to provide hard copy data retention of change of state, operator-initiated actions, management reports, graphics and trended information. Printers, which can be interfaced, include the following:
 - 1. Latest A3 LASERJET Colour printer
 - 2. Receive only (RO) printer
 - 3. Main control station to be provided with one colour and two receive only printers. Secondary stations to be provided with one colour and one receive printer.

2.8 LCD DISPLAYS

- A. Provide LCD displays.

2.9 FIELD DEVICES AND CONTROLS

- A. Provide all necessary transducers, flow and level switches, pressure and temperature sensors, transmitters, etc... Where applicable to satisfy all functions required.
- B. Proof of fan operation shall be by means of air flow switches. Proof of pump operation shall be by means of water flow switches.
- C. All temperature and pressure transmitters shall be equipped with local display.

2.10 SCHEDULE OF SYSTEM GRAPHICS

A. HVAC Control:

1. Equipment: Show layout of all chillers, pumps, cooling towers...
2. Control Points: Show all control points related to all equipment indicated above as per schedule of functional point list and control diagrams.

B. Plumbing Control:

1. Water Softener: Show all control functions as per functional point list.
2. Location plan for each floor, indicating flow alarm devices and zone limits with colour change status.

C. Electrical Control:

1. Power Distribution System: System overview with indication of list feeders, main feeders, ties breaker status, by colour change. Show all control functions as per functional point list.

2.11 SCHEDULE OF FUNCTIONS TO BE MONITORED AND / OR CONTROLLED

A. Mechanical Systems

1. As per Mechanical BMS schedule of points (all points are physical points) that must be prepared by the contractor/BMS specialist and approved by the consultant.

B. Electrical Systems

2. As per Electrical BMS schedule of points (all points are physical points) that must be prepared by the contractor/BMS specialist and approved by the consultant.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that conditioned control rooms are ready to receive work.
- B. Verify field measurements are as shown on shop drawings and as instructed by manufacturer.
- C. Verify that required utilities are available, in proper locations, and ready for use.
- D. Correct unsatisfactory conditions.

3.2 INTERFACE WITH OTHER PRODUCTS

- A. Connect HVAC control devices under provisions of Division 15 related Sections.
- B. Connect motor controllers, electrical sensing and measurement devices, electrical controls and relays, programmable logic controller, under provisions of Divisions 14 and 16 related Sections.

3.3 FIELD QUALITY CONTROL

- A. Test each sequence of building management system by simulation of normal, off-normal, and alarm conditions.

3.4 ON-SITE TESTING

- A. Provide Engineer-approved operation and acceptance testing of the complete system. The Engineer will witness all tests.
- B. Field Test: When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on line. All testing, calibrating, adjusting and final field tests shall be completed. Provide a detailed cross check of each sensor within the system by making a comparison between the reading at the sensor and a standard traceable to the National Bureau of Standards. Provide a cross check of each control point within the system by making a comparison between the control command and the field-controlled device. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power. Submit the results of functional and diagnostic tests and calibrations to the Engineer for final system acceptance.
- C. Compliance Inspection Checklist: Submit in the form requested, the following items of information to the Engineer for verification of compliance to the project specifications. Failure to comply with the specified information all constitute non-performance of the contract. The Contractor shall submit written justification for each item in the checklist that he is unable to comply with. The Engineer will initial and date the checklist to signify Contractor's compliance before acceptance of system.
 - 1. Verify to the Engineer in letter form that supplier has in-place support facility. Letter shall show location of support facility, name and titles of technical staff, engineers, supervisors, fitters, electricians, managers and all other personnel responsible for the completion of the work on this project.
 - 2. Submit in data sheet form or official government approval form compliance to F.C.C. Regulation, Part 15, Section 15.
 - 3. Manually generate an alarm at a remote Controller as selected by the Engineer to demonstrate the capability of the workstation and alarm printer to receive alarms within 5 seconds.
 - 4. Disconnect an operator workstation in the central control room and manually generate an alarm at a remote Controller to demonstrate the capability of the system printer to receive alarms when the workstation is disconnected from the system.

5. Disconnect one Controller from the network to demonstrate that a single device failure shall not disrupt or halt peer-to-peer communication. Panel to be disconnected shall be selected by the Engineer.
6. At a Controller of the Engineer's choice, display on the portable operator's terminal:
 - a. Setpoints and status conditions, i.e., on or off for a system or piece of equipment attached to that panel as well as for points at another Controller on the network, as selected by the Engineer.
 - b. The diagnostic results as specified for a system or piece of equipment attached to that panel as well as for a system or piece of equipment attached to another Controller.
 - c. The ability to add a new point to the Controller with the POT and have it automatically uploaded to the workstation to modify that panel's stored database.

3.5 FIELD SERVICES

- A. Adjust setpoints, alarm points, and display configurations so that system performs as specified.
- B. Include installing and debugging hardware and software. Perform hardware configuration revisions required to accommodate software patches.
- C. Enter building management database and provide backup copy.

3.6 CLEANING

- A. Clean equipment finishes interiors of equipment cabinets.

3.7 SERVICE AND GUARANTEE

- A. General Requirements: Provide all services, materials and equipment necessary for the successful operation of the entire BACS system for a period of one year after completion of successful performance test. Provide necessary material required for the work. Minimize impacts on facility operations when performing scheduled adjustments and non-scheduled work.
- B. Description of Work: The adjustment and repair of the system includes all computer equipment, software updates, transmission equipment and all sensors and control devices. Provide the manufacturer's required adjustment and all other work necessary.
- C. Personnel: Provide qualified personnel to accomplish all work promptly and satisfactorily. Owner shall be advised in writing of the name of the designated service representative, and of any changes in personnel.

- D. Schedule of Work: Provide two minor inspections at 6-month intervals and two major inspections offset equally between the minor inspections to effect quarterly inspection of alternating magnitude, and all work required as specified. Minor inspection shall include visual checks and operational tests of all equipment delivered. Major inspections shall include all work described for minor inspections and the following work:
1. Clean all equipment, including interior and exterior surfaces.
 2. Perform signal, voltage and system isolation checks of system workstations and peripheral.
 3. Check and calibrate each field device. Check all Analog points and digital points.
 4. Run all diagnostics and correct all previously diagnosed problems.
 5. Resolve and correct any previous outstanding problems.
 6. Provide detailed report after each inspection.
- E. Emergency Service: Owner will initiate service calls when the system is not functioning properly. Qualified personnel shall be available to provide service to the complete system. Furnish Owner with a telephone number where service representative can be reached at all times. Service personnel shall be at the site within 24 hours after receiving a request for service. Restore the control system to proper operating condition within 3 days.
- F. Operation: Performance of scheduled adjustments and repair shall verify operation of the system as demonstrated by the initial performance test.
- G. Systems Modifications: Provide any recommendations for system modification in writing to Owner. Do not make any system modifications, including operating parameters and control settings, without prior approval of Owner. Any modifications made to the system shall be incorporated into the operations and maintenance manuals, and other documentation affected.
- H. Software: Provide all software updates and verify operation in the system. These updates shall be accomplished in a timely manner, fully coordinated with the system operators, and shall be incorporated into the operations and maintenance manuals, and software documentation.

3.8 DEMONSTRATION

- A. Provide systems demonstration under provisions of the Contract Documents.

3.9 TRAINING

- A. The Contractor shall provide competent instructors to give full instruction to designated personnel in the adjustment, operation and maintenance of the system installed rather than a general training course. Instructors shall be thoroughly familiar with all aspects of the subject matter they are to teach. All training shall be held during normal work hours as follows:

B. Training shall include:

1. Explanation of drawings, operations and maintenance manuals.
2. Walk-through of the job to locate control components.
3. Operator workstation and peripherals
4. Controller operation/function
5. Operator control functions including graphic generation and field panel programming.
6. Operation of portable operator's terminal.
7. Explanation of adjustment, calibration and replacement procedures.

C. Provide additional training quarterly for a period of one year from final completion of the project.

END OF SECTION 255000