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Project Manual

Specifications
for

Rama Road Elementary School
Pneumatic to DDC Controls Replacement

1035 Rama Rd.
Charlotte, NC 28211

Construction Documents
December 9, 2022

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Document Revision History

No.	Date	Updates
1	01/06/23	230902 – BAS Point Naming and Tagging Guideline 232923 – Variable Frequency Drives
2	02/07/23	230900 – Energy Management System and Building Automation System for HVAC and Lighting Control

SECTION 230500 – COMMON WORK RESULTS FOR HVAC

PART 1 - GENERAL

1.1 RELATED PROVISIONS

A. These specifications and the accompanying drawings shall include the furnishing of all labor, tools, materials, fixtures, transportation, appurtenances, and service necessary and incidental to the installation of a complete and operative system as indicated and intended on the Drawings and as herein specified.

B. Contractor shall coordinate the work and equipment of this division with the work and equipment specified elsewhere to assure a complete and satisfactory installation. Work such as excavation, backfill, concrete, flashing, etc., which is required by the work of this Division of the Specifications, shall be provided by this Division unless otherwise indicated.

C. Minor details not usually shown or specified, but necessary for the proper installation and operation, shall be included in the work, the same as if herein specified or shown.

1.2 DESCRIPTION OF THE WORK

A. Work included under this Division includes installation of a new DDC control system for the existing HVAC systems. The systems shall be installed complete, with controllers, instrumentation, valves, piping, and insulation as hereinafter called for. Miscellaneous items including conduits to be provided as indicated.

B. It shall be the responsibility of the Contractor to provide a complete and operating system according to the true intent and meaning of the plans and specifications and all pipe, controls, and equipment, etc.

1.3 DEFINITION

A. The word "Contractor" as used in this section of the Specifications refers to the HVAC Contractor unless specifically noted otherwise. The word "provide" means furnish, fabricate, complete, install, erect, including labor and incidental materials, necessary to complete in place and ready for operation or use the items referred to or described herein, and/or as shown or referred to on the Contract Drawings.

1.4 HVAC CONTRACTOR QUALIFICATIONS

A. It is assumed that the contractor has had sufficient general knowledge and experience to anticipate the needs for a construction of this nature. The contractor shall furnish all items required to complete the construction in accordance with reasonable interpretation of the intent of the Drawings and Specifications. Any minor items required by Code, law or regulations shall be provided whether or not specified or specifically shown.

B. All work must be done by first class and experienced mechanics properly supervised, and it is understood that the Engineer has the right to stop any work that is not being properly done and has the right to demand that any incompetent workman be removed from the job and a competent workman be substituted therefor.

C. All work must be done in strict accordance with standards of ASME, ASHRAE, and the building laws of all character in force in the locality where the apparatus is being installed. All work must also be in accordance with rules and regulations of the National Board of Fire Underwriters.

1.5 DUTIES OF CONTRACTOR

A. Contractor is responsible for familiarizing himself with the details of the construction of the building. Work under these specifications installed improperly or which requires changing due to improper reading or interpretation of building plans shall be corrected and changed as directed by Engineer

without additional cost to the Owner.

B. Contractor shall leave the premises in a clean and orderly manner upon completion of work and shall remove from premises all debris that has accumulated during the progress of the work. The HVAC Contractor shall have the permanent HVAC systems in sufficient readiness for commissioning.

1.6 CODES, RULES, PERMITS, AND FEES

A. The contractor shall give all necessary notices, obtain all permits, and pay all government sales taxes, fees and other costs including utility connections or extension, in connection with his work; file all necessary plans, prepare all documents, and obtain all necessary approvals of all governmental departments having jurisdiction; obtain all required certificates for inspection for his work and deliver same to the Engineer before request for acceptance and final payment for the work.

B. The contractor shall include in the work, without extra cost to the Owner, any labor, materials, services, apparatus, ordinances, rules, and regulations as required to complete the project in accordance with the intent of the drawings.

C. All materials furnished, and all work installed shall comply with the National Fire Codes of the National Fire Protection Association, with the requirements of all governmental departments having jurisdiction.

1.7 SURVEYS AND MEASUREMENTS

A. The contractor shall base all measurements, both horizontal and vertical, from established benchmarks. All work shall agree with these established lines and levels. Verify all measurements at the site and check correctness of same as related to the work.

B. Should the contractor discover any discrepancy between actual measurements and those indicated, which prevents following good practice or the intent of the drawings and Specifications, he shall notify the Engineer and shall not proceed with his work until he has received instructions from the Engineer.

1.8 PLANS

A. Except where dimensions are shown, mechanical plans are diagrammatic. The plans are not intended to show each fitting, valve, pipe or pipe hanger, or a complete detail of all the work to be done but are for the purpose of illustrating the type of system, pipe, and duct sizes, etc. and special conditions considered necessary for the experienced mechanic to take off his material and lay out his work. Contractor shall be responsible for taking such measurements as may be necessary at the job and adapting his work to the local conditions.

1.9 DRAWINGS AND SPECIFICATIONS

A. Plans are diagrammatic, and it sometimes occurs that conditions exist in buildings which require certain changes in drawings and specifications. In event that such changes are necessary, the same are to be made by Contractor without expense to the Owner, provided however, that such changes, do not require furnishing more material or performing more labor than the true intent of the drawings and specifications demand.

B. It is understood that while the drawings are to be followed as closely as circumstances will permit, the Contractor is held responsible for the installation of the system according to the true intent and meaning of the drawings. Anything not entirely clear on the drawings or in the specifications will be fully explained if application is made to the Engineer. Should however, conditions arise where in the judgment of the Contractor certain changes would be advisable, Contractor will communicate with Engineer and secure approval of the changes before going ahead with the work.

C. The electrical and mechanical systems for this job have been designed based on the mechanical equipment listed or data given herein or on the drawings. It shall be the responsibility of the Contractor to determine that the electrical service outlets, wiring, conduit, and all overcurrent protective and safety

devices furnished are adequate to meet Code Requirements for the equipment which he proposes to use. Changes required in the electrical system to accommodate the proposed mechanical equipment shall be worked out and the details submitted for approval. The cost of making the necessary changes to the electrical system shall be the responsibility of the Contractor.

1.10 SHOP DRAWINGS

A. All items submitted to Engineer for review shall bear stamp or notation indicating Contractor's prior review and approval.

B. Any Electrical or other changes required by substituted equipment to be made at no change in contract price.

C. Submit manufacturer's certified performance data for all equipment.

D. Coordinate installation drawings with other parts of the work, whether specified in this Division or other Divisions.

E. Approval of shop drawings by the Engineer shall not relieve the Contractor from his obligation to provide equipment, control, and operation to the true intent of plans and specifications.

F. The Contractor shall submit to the Engineer, within ten (10) days after approval of bids by the owner, a list indicating the manufacturer of all equipment and materials which he proposes to use. After that date, no substitution will be approved, and all items shall be as specified.

1.11 SCAFFOLDING, RIGGING, HOISTING

A. This contractor shall furnish all scaffolding rigging, hoisting, and services necessary to erection and delivery into the premises of any equipment and apparatus furnished. Remove same from premises when no longer required.

1.12 FOUNDATIONS, SUPPORTS, PIERS, ATTACHMENTS

A. Contractor shall furnish and install all necessary foundations, supports, pads, bases, and piers required for all air conditioning equipment, piping, pumps, tanks, compressors, and for all other equipment furnished under this contract.

1.13 CUTTING AND PATCHING

A. The Contractor shall do all cutting, fitting, and patching as required to install piping and equipment except openings through the roof shall be provided by the General Contractor. Patching shall be done by mechanics skilled in the various trades and work shall match the existing work.

B. All exposed openings in walls and floors for piping shall be core drilled. Cutting of holes by hand will not be allowed.

C. Provide all required protection including but not limited to, welding blankets, dust covers, shoring bracing and supports to maintaining structural integrity, safety, and cleanliness of the work.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Provide equipment complete with all components and accessories necessary to its satisfactory operation.

B. Listing of a manufacturer's name in this Division does not infer conformity to all requirements of the Contract Documents, nor waive requirements thereof.

PART 3 - EXECUTION

3.1 MAINTENANCE AND OPERATING INSTRUCTIONS

A. Upon completion of all work, the Contractor shall furnish a complete set of operating instructions for all equipment. These shall contain instructions for the operation and maintenance of all equipment. Where such is not furnished by the manufacturer, the contractor shall give written instructions to the owner for the maintenance of the equipment involved.

C. All above ceiling equipment shall be accessible using a standard step ladder. No special scaffolding or other means of accessibility will be acceptable.

3.2 ACCESS DOORS OR PANELS

A. Provide duct access doors of approved construction at any apparatus requiring service and inspection. Doors shall suit finish in which installed.

3.3 ITEMS OF ELECTRICAL EQUIPMENT

A. All electrical work shall be done by properly licensed electrical mechanics in accordance with the specifications under supervision of a licensed Electrical Contractor.

B. The Electrical Contractor shall provide all power wiring to motor starter and/or disconnect switch and from starter/disconnect switch to motor. The Controls Contractor shall provide all control wiring, low voltage, or line voltage, as required for the operation of all mechanical equipment. All control devices such as motor starters, thermostats, switches, etc. shall be provided by the Controls Contractor.

C. All motor starters shall be provided with a “hand-off-auto” switch on the starter cover.

D. All items of mechanical equipment electrically operated shall be in complete accordance with electrical division of the specifications. Mechanical equipment, other than individually mounted motors, shall be factory prewired so that it will only be necessary to bring connections to a single set of terminals.

E. Mechanical equipment electrical components shall all be bonded together and connected to electrical system ground.

F. All mechanical equipment electrical components shall be U.L. listed and labeled.

G. No joints shall be allowed in piping that crosses cable trays. Cable tray installation shall be coordinated with all other trades prior to installation. Where water piping must cross a cable tray, a drip pan shall be required.

3.4 WARRANTY AND SERVICE

A. Upon completion of all work, the Contractor shall check the system out so that all motor bearings are greased as required and have all systems balanced. He shall be responsible for original service, of starting the system up, and providing one set of replacement filters after final acceptance.

B. All equipment shall carry a full one-year warranty with a five-year warranty on the cooling cycle on all packaged type equipment in accordance with Division 01 of the specifications.

3.5 INSPECTION AND ACCEPTANCE TEST

A. The project will be checked periodically as construction progresses. The Contractor shall be responsible for notifying the Engineer at least 48 hours in advance when any work to be covered up is ready for inspection. No work will be covered up until approved by the Engineer.

B. Upon completion of erection of all equipment and work specified herein and shown approved shop drawings, and at the time designated by the engineer, the contractor shall start all apparatus, making

necessary tests as directed and as specified herein, and make adjustments of all parts of all equipment before acceptance of equipment by the owner. The contractor must demonstrate to the owner, by performance, that all equipment operates as specified and meets the guarantee called for.

C. Tests shall include satisfactory evidence that all systems operate as called for on the drawings, and that all pieces of equipment operate at specified ratings under specified operating conditions.

D. The contractor shall furnish all fuel and power required for these purposes and provide the proper and necessary help required to operate the system while tests are being made.

E. All drainage piping shall be tested by filling with water to a point 10' above the underground drains or to point of discharge to grade and let stand thus filled for 3 hours.

F. Tests on all pipe work shall be subject to the inspection of the Engineer. He shall be given 24-hours' notice when a section pipe is to be tested and the test shall not be removed until permission is given by the Engineer.

3.6 AS BUILT DRAWINGS

A. As the job progresses, all deviations from the arrangements, piping runs, equipment locations, etc., shown on the Contract Documents shall be marked with red ink. These prints shall not be used for any other purpose than to be marked up as "As-Built" Drawings.

3.7 OWNER TRAINING

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 the equipment listed below:

1. DDC Control Systems

B. Extent of Training:

1. Base extent of training on scope and complexity of equipment installed 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 the number days of training indicated below.
      1) DDC Control Systems - 2 days (16 hours)
   b. Stagger training over multiple training classes to accommodate Owner's requirements. All training shall occur before end of warranty period.

D. Training Attendee List and Sign-in Sheet:

1. Request from Owner in advance of training a proposed attendee list with name, phone number and e-mail address.
2. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
3. At end of each training day, send Owner an e-mail with an attachment of scanned copy (PDF) of circulated sign-in sheet for each session.

E. 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

F. Training Outline:

1. Submit training outline for Owner review at least **10** business day before scheduling training.
2. Outline shall include a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session and synopses for each lesson planned.

G. On-Site Training:

1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power and data connectivity for instructor and each attendee.
2. Instructor shall provide training materials, projector, and other audiovisual equipment used in training.
3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. On-site training shall include regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration, and service requirements.
5. Operator workstation provided with DDC system shall be used in training. If operator workstation is not indicated, provide a temporary workstation to convey training content.

I. Training Content:

1. Basic operation of each system.
2. Understanding each unique product type installed including performance and service requirements for each.
3. Understanding operation of each system and equipment controlled by the DDC system including sequences of operation, each unique control algorithm, and each unique optimization routine.

END OF 230500

SECTION 230513 – COMMON MOTOR REQUIRMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section includes general requirements for single-phase, polyphase, and general-purpose motors for use on HVAC systems up to 600 V.

1.3 SUBMITTALS

A. Product Data: Include manufacturer's technical literature for each motor. Indicate dimensions, capacities, performance characteristics, electrical characteristics, complete list of options provided, finishes for materials, and installation and startup instructions for each type of product indicated.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, power wiring diagrams, method of field assembly, components, and specific location and size of each assembly and field connection.

C. Operation and Maintenance Data: Include instructions for starting and operating motor.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Baldor
2. Marathon
3. General Electric
4. AO Smith
5. Dayton
6. WEG

2.2. GENERAL MOTOR REQUIREMENTS

A. Comply with NEMA MG 1 unless otherwise indicated.

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

2.3 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 40°C and at altitude of 3300 feet above sea level.

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

2.4 POLYPHASE MOTORS

A. Polyphase motors, unless otherwise indicated, shall be in accordance with NEMA MG 1, Design B, medium induction open drip-proof (ODP) type.

B. Efficiency: Premium efficiency

C. Service Factor: 1.15

D. Multispeed Motors: Variable torque
   1. For motors with 2:1 speed ratio: consequent pole, single winding.
   2. For motors with other than 2:1 speed ratio: separate winding for each speed.

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

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

H. Temperature Rise: Match insulation rating.

I. Insulation: Class F

J. Code Letter Designation:
   1. Motors 15 HP and larger: NEMA starting Code F or Code G.
   2. Motors smaller than 15 HP: Manufacturers standard starting characteristics.

K. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.

2.5 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

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

B. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.
   1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
   2. Energy and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
   3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
   4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

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

2.6 SINGLE-PHASE MOTORS

A. Constant-speed motors larger than 1/20 HP and less than 1 HP shall be one of the following, to suit starting torque and requirements of specific motor application.
   1. Permanent-split capacitor
   2. Split phase
   3. Capacitor start, inductor run
   4. Capacitor start, capacitor run

B. Constant-speed motors 1/20 HP and Smaller: Shaded-pole type

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

D. Variable-speed Motors: Shall be electronic commutation motors (ECM), brushless DC motors with internal circuitry to convert AC power supplied to DC power to operate the motor. Motor shall be speed-controllable via internal circuitry down to 20% of full speed via 0-10 VDC or 4-20mA controller output signal from the building DDC system. Motor shall be a minimum of 85% efficient at all speeds.

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

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

PART 3 - EXECUTION

3.1 GENERAL

A. Install motors on motor mounting systems in accordance with motor manufacturer's instructions, securely anchored to resist torque, drive thrusts, and other external forces inherent in mechanical work.

B. Secure sheaves and other drive units to motor shafts with keys and Allen set screws, except motors of 1/3 HP and less may be secured with Allen set screws on flat surface of shaft. Unless otherwise indicated, set motor shafts parallel with machine shafts.

END OF 230513

SECTION 230519 – METERS AND GAGES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section includes:

1. Liquid-in-glass thermometers
2. Thermowells
3. Dial-type pressure gages
4. Gage attachments
5. Test plugs
6. Test-plug kits

1.3 SUBMITTALS

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

B. Wiring Diagrams: For power, signal, and control wiring.

C. Product Certificates: For each type of meter and gage, from manufacturer.

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

PART 2 - PRODUCTS

2.1 LIQUID-IN-GLASS THERMOMETERS

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

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Flo Fab Inc
   b. Tel-Tru Manufacturing Company
   c. Trerice, H. O. Co
   d. Weiss Instruments, Inc.
2. Standard: ASME B40.200
3. Case: Cast aluminum; 7-inch nominal size unless otherwise indicated
4. Case Form: Adjustable angle unless otherwise indicated
5. Tube: Glass with magnifying lens and blue or red organic liquid
6. Tube Background: Nonreflective aluminum with permanently etched scale markings graduated in deg F
7. Window: Glass
8. Stem: Aluminum and of length to suit installation
   a. Design for Air-Duct Installation: With ventilated shroud
   b. Design for Thermowell Installation: Bare stem
9. Connector: 1-1/4 inches, with ASME B1.1 screw threads
10. Accuracy: ±1 % of scale range or one scale division, to a maximum of 1.5 % of scale range.

2.2 DUCT-THERMOMETER MOUNTING BRACKETS

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

stem.

2.3 THERMOWELLS

A. Thermowells:

1. Standard: ASME B40.200
2. Description: Pressure-tight, socket-type fitting made for insertion into piping tee fitting
3. Material for Use with Copper Tubing: Copper nickel (90-10)
4. Material for Use with Steel Piping: Steel
5. Type: Stepped shank unless straight or tapered shank is indicated
6. External Threads: NPS 1/2, NPS 3/4, or NPS 1, ASME B1.20.1 pipe threads
7. Internal Threads: 1/2, 3/4, and 1 inch, 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.

2.4 PRESSURE GAGES

A. Direct-Mounted, Metal-Case, Dial-Type Pressure Gages:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Flo Fab Inc
   b. Tel-Tru Manufacturing Company
   c. Trerice, H. O. Co
   d. Watts Regulator Co.; a div. of Watts Water Technologies, Inc
   e. Weiss Instruments, Inc.
2. Standard: ASME B40.100
3. Case: Liquid-filled or sealed type(s); cast aluminum or drawn steel; 4-1/2-inch nominal diameter
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated
5. Pressure Connection: Brass, with NPS 1/4 or NPS 1/2, ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
6. Movement: Mechanical, with link to pressure element and connection to pointer.
7. Dial: Nonreflective aluminum with permanently etched scale markings graduated in psi.
8. Pointer: Dark-colored metal
9. Window: Glass
10. Ring: Metal
11. Accuracy: Grade B, plus or minus 2 percent of middle half of scale range

2.5 GAGE ATTACHMENTS

A. Snubbers: ASME B40.100, brass; with NPS 1/4 or NPS 1/2, ASME B1.20.1 pipe threads and piston-type surge-dampening device. Include extension for use on insulated piping.

B. Siphons: Loop-shaped section of steel pipe with NPS 1/4 or NPS 1/2 pipe threads

C. Valves: Brass ball, with NPS 1/4 or NPS 1/2, ASME B1.20.1 pipe threads

2.6 TEST PLUGS

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

1. Flow Design, Inc

2. Trerice, H. O. Co
3. Watts Regulator Co.; a div. of Watts Water Technologies, Inc
4. Weiss Instruments, Inc

B. Description: Test-station fitting made for insertion into piping tee fitting.

C. Body: Brass or stainless steel with core inserts and gasketed and threaded cap. Include extended stem on units to be installed in insulated piping.

D. Thread Size: NPS 1/4 or NPS 1/2, ASME B1.20.1 pipe thread

E. Minimum Pressure and Temperature Rating: 500 psig at 200 °F

F. Core Inserts: Chlorosulfonated polyethylene synthetic and EPDM self-sealing rubber.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install thermowells with socket extending a minimum of 2 inches 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 direct-mounted pressure gages in piping tees with pressure gage located on pipe at the most readable position.

G. Install valve and snubber in piping for each pressure gage for fluids (except steam).

H. Install test plugs in piping tees.

I. Install permanent indicators on walls or brackets in accessible and readable positions.

J. Install connection fittings in accessible locations for attachment to portable indicators.

K. Install thermometers in the following locations:

1. Inlet and outlet of each chiller (condenser and evaporator).
2. Inlet and outlet of each hydronic boiler.
3. Inlet and outlet of each hydronic coil in air-handling units.

L. Install pressure gages in the following locations:

1. Suction and discharge of each pump.

M. All thermometers shall be legible from ground level.

3.2 CONNECTIONS

A. Install meters and gages adjacent to machines and equipment to allow service and maintenance of meters, gages, machines, and equipment.

3.3 ADJUSTTING

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 chiller shall be the following:

1. Industrial-style, liquid-in-glass type.
2. Test plug with EPDM self-sealing rubber inserts.

B. Thermometers at inlet and outlet of each hydronic boiler shall be the following:

1. Industrial-style, liquid-in-glass type.
2. Test plug with EPDM self-sealing rubber inserts.

C. Thermometers at inlet and outlet of each hydronic coil in air-handling units and built-up central systems shall be the following:

1. Industrial-style, liquid-in-glass type.
2. Test plug with EPDM self-sealing rubber inserts.

D. Thermometer stems shall be of length to match thermowell insertion length.

3.5 THERMOMETER SCALE RANGE SCHEDULE

A. Scale Range for Chilled Water Piping: 0 to 100 °F

B. Scale Range for Heating Hot Water Piping: 20 to 240 °F

C. Scale Range for Dual Temperature Water Piping: 30 to 200 °F

3.6 PRESSURE GAGE SCHEDULE

A. Pressure gages at discharge of each pressure-reducing valve shall be the following:

1. Liquid-filled or sealed, direct-mounted, metal case.
2. Test plug with EPDM self-sealing rubber inserts.

B. Pressure gages at suction and discharge of each pump shall be the following:

1. Liquid-filled or sealed, direct-mounted, metal case.
2. Test plug with EPDM self-sealing rubber inserts.

3.7 PRESSURE GAGE SCALE RANGE SCHEDULE

A. Scale Range for Chilled Water Piping: 0 to 200 psi

B. Scale Range for Heating Hot Water Piping: 0 to 200 psi

END OF 230519

SECTION 230523 – GENERAL DUTY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section includes:

1. Copper-alloy ball valves
2. Ferrous-alloy ball valves
3. Ferrous-alloy butterfly valves
4. Bronze check valves
5. Gray-iron swing check valves
6. Ferrous-alloy wafer check valves
7. Bronze globe valves
8. Cast-iron globe valves

B. Related Sections include the following:

1. Division 23 Section 230719 – HVAC Piping Insulation.
2. Division 23 Section 230900 Management System and Building Automation System for HVAC and Lighting Control for control valves and actuators.

1.3 DEFINITIONS

A. The following are standard abbreviations for valves:

1. CWP: Cold working pressure
2. EPDM: Ethylene-propylene-diene terpolymer rubber
3. PTFE: Polytetrafluoroethylene plastic
4. TFE: Tetrafluoroethylene plastic

1.4 SUBMITTALS

A. Product Data: For each type of valve indicated. Include body, seating, and trim materials; valve design; pressure and temperature classifications; end connections; arrangement; dimensions; and required clearances. Include list indicating valve and its application. Include rated capacities; shipping, installed, and operating weights; furnished specialties; and accessories.

1.5 QUALITY ASSURANCE

A. ASME Compliance: ASME B31.9 for building services piping valves.

B. ASME Compliance for Ferrous Valves: ASME B16.10 and ASME B16.34 for dimension and design criteria.

C. NSF Compliance: NSF 61 for valve materials for potable-water service.

1.6 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 angle and globe valves closed to prevent rattling.
4. Set ball valves open to minimize exposure of functional surfaces.
5. Set butterfly valves closed or slightly open.
6. 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 handwheels or stems as lifting or rigging points.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Where paragraphs below introduce lists, the following requirements apply for product selection:

1. Manufacturers: Subject to compliance with requirements, provide products by the manufacturers specified.

2.2 VALVES - GENERAL

A. Refer to Part 3 "Valve Applications" for applications of valves.

B. Bronze Valves: NPS 2 and smaller with threaded ends, unless otherwise indicated.

C. Ferrous Valves: NPS 2-1/2 and larger with flanged ends, unless otherwise indicated.

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

E. Valve Sizes: Same as upstream pipe, unless otherwise indicated.

F. Valve Actuators:

1. Gear Drive: For quarter-turn valves NPS 8 and larger.
2. Handwheel: For valves other than quarter-turn types.
3. Lever Handle: For quarter-turn valves NPS 6 and smaller, except plug valves.
4. Wrench: For plug valves with square heads. Furnish Owner with 1 wrench for every 10 plug valves, for each size square plug head.

G. Extended Valve Stems: On insulated valves.

H. Valve Flanges: ASME B16.1 for cast-iron valves, ASME B16.5 for steel valves, and ASME B16.24 for bronze valves.

I. Valve Grooved Ends: AWWA C606.

1. Solder Joint: With sockets according to ASME B16.18.
   a. Caution: Use solder with melting point below 840°F for angle, check, and globe valves; below 421°F for ball valves.
2. Threaded: With threads according to ASME B1.20.1.

J. Valve Bypass and Drain Connections: MSS SP-45.

2.3 COPPER ALLOY BALL VALVES

A. Manufacturers:

1. Conbraco Industries, Inc.; Apollo Div
2. Crane Co.; Crane Valve Group; Jenkins Valves
3. Crane Co.; Crane Valve Group; Stockham Div
4. Grinnell Corporation
5. Jamesbury, Inc
6. Kitz Corporation of America
7. Legend Valve & Fitting, Inc
8. NIBCO INC
9. Watts Industries, Inc.; Water Products Div

B. Copper-Alloy Ball Valves, General: MSS SP-110.

C. One-Piece, Copper-Alloy Ball Valves: Brass or bronze body with chrome-plated bronze ball, PTFE or TFE seats, full port, and 400-psig minimum CWP rating.

D. Two-Piece, Copper-Alloy Ball Valves: Bronze body with regular-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.

E. Three-Piece, Copper-Alloy Ball Valves: Bronze body with regular-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.

F. Port Size: Full Port for 1” and smaller; Standard Port for 1-1/4” and larger.

2.4 FERROUS ALLOY BALL VALVES

A. Manufacturers:

1. Conbraco Industries, Inc.; Apollo Div
2. Crane Co.; Crane Valve Group; Stockham Div
3. Hammond Valve
4. Jamesbury, Inc
5. Kitz Corporation of America.
6. Milwaukee Valve Company
7. NIBCO INC.
8. Worcester Controls

B. Ferrous-Alloy Ball Valves, General: MSS SP-72, with flanged ends.

C. Ferrous-Alloy Ball Valves: Class 150, full port.

D. Ferrous-Alloy Ball Valves: Class 300, full port.

2.5 BUTTERFLY VALVES

A. Manufacturers:

1. Ferrous Alloy Butterfly Valves

a. Crane Co.; Crane Valve Group; Stockham Div.
b. Grinnell Corporation
c. Hammond Valve
d. Kitz Corporation of America

e. Milwaukee Valve Company
f. NIBCO INC
g. Red-White Valve Corp
h. Tyco International, Ltd.; Tyco Valves & Controls
i. Watts Industries, Inc.; Water Products Div

2. Grooved-End, Ductile-Iron Butterfly Valves:

a. Grinnell Corporation
b. Hammond Valve
c. Milwaukee Valve Company
d. NIBCO INC
e. Victaulic Co. of America

B. Ferrous-Alloy Butterfly Valves, General: MSS SP-67, Type I, for tight shutoff, with disc and lining suitable for potable water, unless otherwise indicated.

C. Flangeless, 150-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Wafer type with one or two-piece stem.

D. Single-Flange, 150-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Wafer-lug type with one or two piece stem.

E. Flanged, 150-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Flanged-end type with one or two-piece stem.

F. Grooved-End, 175-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Ductile-iron or steel body with grooved or shouldered ends.

2.6 BRONZE CHECK VALVES

A. Manufacturers:

1. Type 2, Bronze, Horizontal Lift Check Valves with Nonmetallic Disc:

a. Cincinnati Valve Co
b. Crane Co.; Crane Valve Group; Crane Valves
c. Crane Co.; Crane Valve Group; Jenkins Valves
d. Crane Co.; Crane Valve Group; Stockham Div
e. Walworth Co

2. Type 2, Bronze, Vertical Lift Check Valves with Nonmetallic Disc:

a. Grinnell Corporation
b. Kitz Corporation of America
c. Milwaukee Valve Company

3. Type 4, Bronze, Swing Check Valves with Nonmetallic Disc:

a. Crane Co.; Crane Valve Group; Crane Valves
b. Crane Co.; Crane Valve Group; Jenkins Valves
c. Crane Co.; Crane Valve Group; Stockham Div
d. Grinnell Corporation
e. Hammond Valve
f. Milwaukee Valve Company

g. NIBCO INC
h. Red-White Valve Corp
i. Walworth Co
j. Watts Industries, Inc; Water Products Div

B. Bronze Check Valves, General: MSS SP-80.

C. Type 2, Class 125, Bronze, Horizontal Lift Check Valves: Bronze body with nonmetallic disc and bronze seat.

D. Type 2, Class 125, Bronze, Vertical Lift Check Valves: Bronze body with nonmetallic disc and bronze seat.

E. Type 2, Class 150, Bronze, Horizontal Lift Check Valves: Bronze body with nonmetallic disc and bronze seat.

F. Type 2, Class 150, Bronze, Vertical Lift Check Valves: Bronze body with nonmetallic disc and bronze seat.

G. Type 2, Class 200, Bronze, Horizontal Lift Check Valves: Bronze body with nonmetallic disc and bronze seat.

H. Type 2, Class 200, Bronze, Vertical Lift Check Valves: Bronze body with nonmetallic disc and bronze seat.

I. Type 4, Class 125, Bronze, Swing Check Valves: Bronze body with nonmetallic disc and bronze seat.

J. Type 4, Class 150, Bronze, Swing Check Valves: Bronze body with nonmetallic disc and bronze seat.

K. Type 4, Class 200, Bronze, Swing Check Valves: Bronze body with nonmetallic disc and bronze seat.

2.7 GRAY IRON CHECK VALVES

A. Manufacturers:

1. Type 2, Gray Iron, Swing Check Valves with Composition to Metal Seats:

a. Crane Co.; Crane Valve Group; Crane Valves
b. Crane Co.; Crane Valve Group; Stockham Div
c. Mueller Co
d. Watts Industries, Inc; Water Products Div

2. Grooved-End, Ductile-Iron Swing Check Valves:

a. Grinnell Corporation
b. Mueller Co
c. Victaulic Co. of America

B. Gray-Iron Swing Check Valves, General: MSS SP-71.

C. Type II, Class 125, gray-iron, swing check valves with composition to metal seats.

D. Type II, Class 250, gray-iron, swing check valves with composition to metal seats.

E. 175-psig CWP Rating, Grooved-End, Swing Check Valves: Ductile-iron body with grooved or

shouldered ends.

2.8 BRONZE GLOBE VALVES

A. Manufacturers:

1. Type 2, Bronze Globe Valves with Nonmetallic Disc:

a. Cincinnati Valve Co
b. Crane Co.; Crane Valve Group; Crane Valves
c. Crane Co.; Crane Valve Group; Jenkins Valves
d. Crane Co.; Crane Valve Group; Stockham Div
e. Grinnell Corporation
f. Hammond Valve
g. Kitz Corporation of America
h. Milwaukee Valve Company
i. NIBCO INC
j. Powell, Wm. Co
k. Red-White Valve Corp
l. Walworth Co.

B. Bronze Globe Valves, General: MSS SP-80, with ferrous-alloy handwheel.

C. Type 2, Class 150, Bronze Globe Valves: Bronze body with PTFE or TFE disc and union-ring bonnet.

2.9 CAST IRON GLOBE VALVES

A. Manufacturers:

1. Type I, Cast-Iron Globe Valves with Metal Seats:

a. Cincinnati Valve Co
b. Crane Co.; Crane Valve Group; Crane Valves
c. Crane Co.; Crane Valve Group; Jenkins Valves
d. Crane Co.; Crane Valve Group; Stockham Div
e. Grinnell Corporation
f. Hammond Valve
g. Kitz Corporation of America
h. Milwaukee Valve Company
i. NIBCO INC
j. Powell, Wm. Co.
k. Red-White Valve Corp
l. Walworth Co.

B. Cast-Iron Globe Valves, General: MSS SP-85.

C. Type I, Class 125, Cast-Iron Globe Valves: Gray-iron body with bronze seats.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Examine piping system for compliance with requirements for installation tolerances and other conditions affecting performance.

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

B. 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.

C. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.

D. Examine threads on valve and mating pipe for form and cleanliness.

E. 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.

F. Do not attempt to repair defective valves; replace with new valves.

3.2 VALVE APPLICATIONS

A. Refer to piping Sections for specific valve applications. If valve applications are not indicated, use the following:

1. Shutoff Service: Ball or butterfly valves.
2. Throttling Service: Ball, butterfly, or globe valves.

B. When valves with specified SWP classes or CWP ratings are not available, the same types of valves with higher SWP class or CWP ratings may be substituted.

C. Hot Water, and Chilled Water Piping: Use the following types of valves:

1. Ball Valves, NPS 2 and Smaller: One-piece, 400-psig CWP rating, copper alloy.
2. Ball Valves, NPS 2-1/2 and Larger: Class 150, ferrous alloy.
3. Butterfly Valves, NPS 2-1/2 and Larger: Flangeless, single-flange or flanged, 150-psig CWP rating, ferrous alloy, with EPDM liner.
4. Grooved-End, Ductile-Iron Butterfly Valves, NPS 2-1/2 and Larger: 175-psig CWP rating.
5. Swing Check Valves, NPS 2 and Smaller: Type 4, Class 150, bronze.
6. Swing Check Valves, NPS 2-1/2 and Larger: Type II, Class 125, gray iron.
7. Grooved-End, Ductile-Iron, Swing Check Valves, NPS 2-1/2 and Larger: 175-psig CWP rating.
8. Globe Valves, NPS 2 and Smaller: Type 2, Class 150, bronze.
9. Globe Valves, NPS 2-1/2 and Larger: Type I, Class 125, bronze-mounted cast iron.

D. Condenser Water Piping: Use the following types of valves:

1. Ball Valves, NPS 2 and Smaller: One-piece, 400-psig CWP rating.
2. Ball Valves, NPS 2-1/2 and Larger: Class 150, ferrous alloy.
3. Butterfly Valves, NPS 2-1/2 and Larger: Flangeless, single-flange or flanged, 150-psig CWP rating, ferrous alloy, with EPDM liner.
4. Grooved-End, Ductile-Iron Butterfly Valves, NPS 2-1/2 and Larger: 175-psig CWP rating.
5. Swing Check Valves, NPS 2 and Smaller: Type 4, Class 150.
6. Swing Check Valves, NPS 2-1/2 and Larger: Type II, Class 125, gray iron.
7. Grooved-End, Ductile-Iron, Swing Check Valves, NPS 2-1/2 and Larger: 175-psig CWP rating.

E. Select valves, except wafer and flangeless types, with the following end connections:

1. For Copper Tubing, NPS 2 and Smaller: Solder-joint or threaded ends, except provide valves with

threaded ends for condenser water services.

2. For Copper Tubing, NPS 2-1/2 to NPS 4: Flanged or threaded ends.
3. For Copper Tubing, NPS 5 and Larger: Flanged ends.
4. For Steel Piping, NPS 2 and Smaller: Threaded ends.
5. For Steel Piping, NPS 2-1/2 to NPS 4: Flanged or threaded ends.
6. For Steel Piping, NPS 5 and Larger: Flanged ends.
7. For Grooved-End, Copper Tubing and Steel Piping: Valve ends may be grooved. Do not use for steam or steam condensate piping.

3.3 VALVE INSTALLATION

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

C. Locate valves for easy access and provide separate support where necessary.

D. Install valves in horizontal piping with stem at or above center of pipe.

E. Install valves in position to allow full stem movement.

F. Install check valves for proper direction of flow.

3.4 JOINT CONSTRUCTION

A. Refer to Division 23 Section "Common Work Results for HVAC" for basic piping joint construction.

B. Grooved Joints: Assemble joints with keyed coupling housing, gasket, lubricant, and bolts according to coupling and fitting manufacturer's written instructions.

C. Soldered Joints: Use ASTM B 813, water-flushable, lead-free flux; ASTM B 32, lead-free-alloy solder; and ASTM B 828 procedure, unless otherwise indicated.

3.5 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.

END OF 230523

SECTION 230523.17 – BALANCING VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes manual balancing valves for hydronic piping systems.

B. Related Sections include the following:

1. Section 230719 “HVAC Piping Insulation” for requirements that relate to valve insulation.

C. Balancing valves shall not be used as manual isolation or service valves. Use appropriate full port valves for equipment and sectional header isolation.

1.2 ACTION SUBMITTALS

A. Product data including model number, performance, Cv ratings, pressure drop, accuracy, size, construction, weights, required upstream and downstream straight pipe diameters, if applicable, and accessories, such as valve insulation kits and measuring meters.

B. Installation, Operation and Maintenance instructions including parts list and trouble-shooting guide.

PART 2 - PRODUCTS

2.1 BALANCING VALVES, CALIBRATED-ORIFICE OR VENTURI

A. Manufacturers:

1. Tour & Anderson (basis-of-design)
2. Bell & Gossett
3. Caleffi 130 series
4. Danfoss STV
5. Nexus
6. Nibco
7. RWV

B. Type: Calibrated orifice or venturi, Y-pattern, globe style

C. Accuracy: ± 3% accuracy within measuring range

D. Minimum Rated Pressure Drop: 2 ft water gage

E. Throttling: Minimum of (4) 360-degree turns of handwheel

F. Body: Bronze, Brass, or copper alloy
   a. For potable water systems, balancing valve shall be lead free per NSF 372.

G. Adjustment Knob: Plastic

H. Drain: Connection for ¾” NPT hose end thread, where specified on Drawings

I. Seat: EPDM or PTFE

J. End Connections: Threaded, pressed, or flanged

K. Measurement Taps: Self-sealing for probe insertion, EPDM seals, regular length (not extended)

L. Locking Mechanism: Memory stop to retain set position

M. CWP Rating: Minimum 125 psig (860 kPa)

N. Maximum Operating Temperature: 250 °F

O. Medium: Water of glycol, propylene up to 50%

P. Insulation: Removable, reusable, insulation kit, with Velcro closure, suitable for hot and cold applications

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install balancing valves in locations indicated on Construction Documents.

B. Install valves so that they are accessible and in a location that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for access, confirm unrestricted ladder placement is possible under occupied condition.

C. Install nameplate with valve identification on valve.

D. Test installed balancing valve per manufacturer's recommended procedure.

END OF 230523.17

SECTION 230529 – HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. Steel pipe hangers and supports.
2. Trapeze pipe hangars.
3. Fastener systems.
4. Equipment supports.

1.2 DEFINITIONS

A. Terminology: As defined in MSS SP-90, "Guidelines on Terminology for Pipe Hangers and Supports."

1.3 PERFORMANCE REQUIREMENTS

A. Design supports for multiple pipes capable of supporting combined weight of supported systems, system contents, and test water.

B. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.

C. Design seismic-restraint hangers and supports for piping and equipment and obtain approval from authorities having jurisdiction.

1.4 SUBMITTALS

A. Product Data: For the following:

1. Steel pipe hangers and supports.
2. Powder-actuated fastener systems.

B. Welding certificates.

1.5 QUALITY ASSURANCE

A. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

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

2.2 STEEL PIPE HANGERS AND SUPPORTS

A. Description: MSS SP-58, Types 1 through 58, factory-fabricated components. Refer to Part 3 "Hanger and Support Applications" Article for where to use specific hanger and support types.

B. Manufacturers:

1. AAA Technology & Specialties Co., Inc
2. B-Line Systems, Inc.; a division of Cooper Industries
3. Empire Industries, Inc
4. ERICO/Michigan Hanger Co
5. Globe Pipe Hanger Products, Inc.
6. National Pipe Hanger Corporation
7. PHD Manufacturing, Inc
8. PHS Industries, Inc
9. Piping Technology & Products, Inc.

C. Galvanized, Metallic Coatings: Pre-galvanized or hot dipped

D. Nonmetallic Coatings: Plastic coating, jacket, or liner

E. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion for support of bearing surface of piping.

2.3 TRAPEZE PIPE HANGERS

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

2.4 FASTENER SYSTEMS

A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened Portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

1. Manufacturers:
   a. Hilti, Inc
   b. Fastenal
   c. ITW Ramset/Red Head.
   d. Masterset Fastening Systems, Inc
   e. MKT Fastening, LLC
   f. Powers Fasteners

B. Mechanical-Expansion Anchors: Insert-wedge-type zinc-coated or stainless steel, for use in hardened Portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

1. Manufacturers:
   a. B-Line Systems, Inc.; a division of Cooper Industries
   b. Empire Industries, Inc
   c. Hilti, Inc
   d. Fastenal
   e. ITW Ramset/Red Head

2.5 EQUIPMENT SUPPORTS

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

2.6 MISCELLANEOUS MATERIALS

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

B. Grout: ASTM C 1107, factory-mixed and packaged, dry, hydraulic-cement, non-shrink and

nonmetallic grout; suitable for interior and exterior applications.

1. Properties: Non-staining, noncorrosive, and nongaseous
2. Design Mix: 5,000-psi, 28-day compressive strength

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT APPLICATIONS

A. Specific hanger and support requirements are specified in Sections specifying piping systems and equipment.

B. Comply with MSS SP-69 for pipe hanger selections and applications that are not specified in piping system Sections.

C. Use hangers and supports with galvanized, metallic coatings for piping and equipment that will not have field-applied finish.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use padded hangers for piping that is subject to scratching.

F. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of non-insulated or insulated stationary pipes, NPS 1/2 to NPS 8.
2. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of non-insulated stationary pipes, NPS 1/2 to NPS 8.

G. 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 8.
2. Carbon or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers, NPS 3/4 to NPS 8, if longer ends are required for riser clamps.

H. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450°F piping installations.

I. 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. Welded-Steel Brackets: For support of pipes from below, or for suspending from above by using

clip and rod. Use one of the following for indicated loads:
a. Light (MSS Type 31): 750 lb
b. Medium (MSS Type 32): 1500 lb
c. Heavy (MSS Type 33): 3000 lb
8. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
9. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.

J. Use powder-actuated fasteners or mechanical-expansion anchors instead of building attachments where required in concrete construction.

3.2 HANGER AND SUPPORT INSTALLATION

A. No hangars shall be supported from a lay-in ceiling grid.

B. Steel Pipe Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure.

C. Fastener System Installation:

1. Install powder-actuated fasteners in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

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

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

F. 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.

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

H. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads 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.

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

J. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and so maximum pipe deflections allowed by ASME B31.1 (for power piping) and ASME B31.9 (for building services piping) are not exceeded.

K. Insulated Piping: Comply with the following:

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 according to ASME B31.1 for power piping and 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.
3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall

span an arc of 180 degrees.

4. Shield Dimensions for Pipe: Not less than the following:
   a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick
   b. NPS 4: 12 inches long and 0.06 inch thick
   c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick

5. Insert Material: Length at least as long as protective shield.

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 smooth bearing surface.

C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.4 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for 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 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 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.

3.6 PAINTING

A. Touch Up: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

1. Apply paint by brush or spray to provide minimum dry film thickness of 2.0 mils.

B. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

END OF 230529

SECTION 230593 – TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section 1.2.A though C below are Charlotte-Mecklenburg Schools (CMS) requirements.

B. Section includes:

1. Testing all mechanical equipment by TAB Specialist to determine that performance is compliant with requirements of the contract documents and adjusting and balancing of systems so that fluid quantities are delivered to locations as required by the contract documents and that the temperature, humidity, and volume may be controlled in accordance with design intent and space requirements.

2. Testing all instructional and performance spaces and report acoustical performance information.

3. Coordination and enabling of testing and balancing activities by Contractor and Mechanical Installer.

4. TAB work shall not imply a guarantee of Mechanical system, nor shall it relieve Contractor or equipment manufacturers of their responsibilities under the contract documents.

5. Balancing Air Systems:
   a. Constant-volume air systems.

6. Balancing Hydronic Piping Systems:
   a. Constant-flow hydronic systems.
   b. Variable-flow hydronic systems.
   c. Primary-Secondary hydronic systems.

C. The Owner will hire an independent Commissioning Agent to commission the Work; however, this shall not relieve the Contractor of his responsibilities. Refer to commissioning plan portion of the specifications. Contractor shall provide all required labor and/or material to comply with the commissioning plan.

D. Work in this section shall be contracted directly by the Contractor. The Mechanical Installer shall coordinate work with the TAB Specialist.

1.3 ABBREVIATIONS AND DEFINITIONS

A. AABC: Associated Air Balance Council

B. ASHRAE: American Society of Heating, Refrigeration, and Air-Conditioning Engineers

C. NEBB: National Environmental Balancing Bureau

D. TAB: Testing, adjusting, and balancing

E. TABB: Testing, Adjusting, and Balancing Bureau

F. TAB Specialist: An entity engaged to perform TAB work

1.4 INFORMATIONAL SUBMITTALS

A. Qualification Data: Within 30 days of Contractor's Notice to proceed, submit documentation that the TAB contractor and this Project's TAB team members meet the qualifications specified in the "Quality Assurance" section of this specification.

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" section of this specification.

D. Certified TAB reports.

E. 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

1.5 QUALITY ASSURANCE

A. Qualifications: Testing and balancing shall be performed by certified, independent firm approved by Owner, specializing in testing and balancing of mechanical systems that is acceptable to Owner, employing full-time employees qualified to perform work of this Section. TAB Specialist shall be a member of AABC or NEBB.

B. TAB Specialist's Supervising Engineer: Qualified professional engineer who is a full-time employee of TAB Specialist firm and experienced in supervising work required by this Section.

C. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE Standard 111, Section 5 - "Instrumentation."

D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 – "Air Balancing."

E. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.3.3 – "System Balancing."

1.6 PROJECT CONDITIONS

A. Testing and balance shall not begin until the system has been completed and is in full working order. The Mechanical Installer shall put all heating, ventilating, and air conditioning systems and equipment into full operation and shall continue the operation of same during each working day of testing and balancing.

1.7 COORDINATION

A. Notice: Provide seven days advance notice for each test. Include scheduled test dates and times.

B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

PART 2 – PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 TAB SPECIALISTS

A. Engage TAB Specialists approved by Owner or submit qualifications of proposed TAB Specialist prior to bid.

3.2 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in system designs that may preclude proper TAB of systems and equipment.

B. Examine systems for installed balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and system outputs, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine ceiling plenums used for supply, return, or relief air to verify that they meet the leakage class of connected ducts and are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

F. Examine equipment performance data including fan and pump curves.

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

G. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.

H. Examine test reports specified in individual system and equipment Sections.

I. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

J. Examine terminal units and verify that they are accessible, and their controls are connected and functioning.

K. Examine strainers. Verify that startup screens are replaced by permanent screens with indicated perforations.

L. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.

M. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

N. Examine system pumps to ensure absence of entrained air in the suction piping.

O. Examine operating safety interlocks and controls on HVAC equipment.

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

3.3 PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures.

B. Upon completion of items of work required, and prior to the commencement of TAB, the Mechanical Contractor shall thoroughly clean all dirt and debris from equipment, ducts, piping systems, fixtures, strainers, and other accessories.

1. All bearings, gear boxes, wearing surfaces, or other equipment components requiring lubrication shall be properly serviced as recommended by the equipment manufacturer, and shall be tagged with the date of service and type of lubricant used. All specified cleaning and protective devices shall then be installed in equipment, piping, plenums, ductwork, etc., and systems shall be placed in continuous operation.

2. All fans shall have been in operation for at least twenty-four hours prior to the start of testing and balancing so that initial stretch of drive belts will have taken place, and all other mechanical equipment, including temperature and operating control devices shall have been adjusted and calibrated for complete and functional operating service.

C. Provide the TAB Specialist copies of all approved equipment, specialties, and control submittal data, together with a set of contract plans and specifications.

D. Provide all thermometer wells, pressure gauge connections, capped duct thermometer openings, as required by the Testing and Balancing Agent. The TAB Specialist shall assist the Mechanical Contractor in locating these devices as the job progresses.

E. Provide sufficient time from the complete installation of all systems to the final established completion date of this project so that testing and balancing can be accomplished.

F. Complete system-readiness checks and prepare reports. Verify the following:

1. Permanent electrical-power wiring is complete.
2. Hydronic systems are filled, clean, and free of air.
3. Automatic temperature-control systems are operational.
4. Equipment and duct access doors are securely closed.
5. Balance, smoke, and fire dampers are open.
6. Isolating and balancing valves are open and control valves are operational.
7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
8. Windows and doors can be closed so indicated conditions for system operations can be met.

3.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance" or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" and in this Section.

1. Comply with requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

1. After testing and balancing, patch probe holes in ducts with plastic plugs.
2. After testing and balancing, install duct access doors.
3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 230713 "Duct 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) units.

3.5 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of system "as-built" duct layouts.

C. For variable-air-volume systems, develop a plan to simulate diversity.

D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.

E. Check airflow patterns from the outdoor air louvers and dampers, and the return and exhaust air dampers through the supply fan discharge and mixing dampers.

F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

G. Verify that motor starters are equipped with properly sized thermal protection.

H. Check dampers for proper position to achieve desired airflow path.

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functionality.

K. Check for proper sealing of air-handling-unit components.

L. Verify that air duct system is sealed.

M. Verify and note the locations of the pressure switches on all hydronic systems.

N. Verify motor rotation on all 3-phase motors.

3.6 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

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

2. Measure fan static pressures as follows to determine actual static pressure:
   a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.
   b. Measure static pressure directly at the fan outlet or through the flexible connection.
   c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.

d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and air-treating equipment.
   a. Report the cleanliness status of filters and the time static pressures are measured.

4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.

5. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

6. Obtain approval from Engineer 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.

7. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure airflow of submain and branch ducts.
   a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.

3. Re-measure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure air outlets and inlets without adjusting.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

D. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Adjust using branch volume dampers rather than extractors and the dampers at air terminals.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.

2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.7 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data, and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against the approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare schematic diagrams of system "as-built" piping layouts.

C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:

1. Open all manual valves for maximum flow.
2. Check liquid level in expansion tank.
3. Check makeup water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation and set at indicated flow.
5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
6. Set system controls so automatic valves are wide open to heat exchangers.
7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.8 PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

A. Measure water flow at pumps. Use the following procedures except for positive-displacement pumps:

1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
   a. If impeller sizes must be adjusted to achieve pump performance, obtain approval from Engineer.
2. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.
   a. Monitor motor performance during procedures and do not operate motors in overload conditions.
3. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
4. Report flow rates that are not within ± 10% of design.

B. Measure flow at all automatic flow control valves to verify that valves are functioning as designed.

C. Measure flow at all pressure-independent characterized control valves, with valves in fully open position, to verify that valves are functioning as designed.

D. Set calibrated balancing valves, if installed, at calculated pre-settings.

E. Measure flow at all stations and adjust, where necessary, to obtain first balance.

1. System components that have a Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.

F. Measure flow at main balancing station and set main balancing device to achieve flow that is 5% greater

than indicated flow.

G. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:

1. Determine the balancing station with the highest percentage over indicated flow.

2. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.

3. Record settings and mark balancing devices.

H. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and system pressures and temperatures, including outdoor air temperature.

I. Measure the differential pressure control valve settings existing at the conclusion of balancing.

J. Check settings and operation of each safety valve. Record settings.

3.9 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. Determine DP set point for pump VFD controller at minimum pressure able to satisfy the worst-case valve pressure requirement.

3.10 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

A. Balance the primary circuit flow first and then balance the secondary circuits.

B. Determine DP set point for pump VFD controller at minimum pressure able to satisfy the worst-case valve pressure requirement.

3.11 PROCEDURES FOR MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer's name, model number, and serial number
2. Motor horsepower rating
3. Motor rpm
4. Efficiency rating
5. Nameplate and measured voltage, each phase
6. Nameplate and measured amperage, each phase
7. Starter thermal-protection-element rating.

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

3.12 PROCEDURES FOR CHILLERS

A. 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 of cooling.

6. For air-cooled chillers, verify condenser fan rotation and record fan and motor data including number of fans and entering and leaving air temperatures.

3.13 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering and leaving air temperatures.

C. Record compressor data.

3.14 PROCEDURES FOR BOILERS

A. Hydronic Boilers: Measure and record entering and leaving water temperatures and water flow.

3.15 PROCEDURES FOR HEAT TRANSFER COILS

A. Measure, adjust, and record the following data for each water coil:

1. Entering and leaving water temperature
2. Water flow rate
3. Water pressure drop
4. Dry-bulb temperature of entering and leaving air
5. Wet-bulb temperature of entering and leaving air for cooling coils
6. Airflow
7. Air pressure drop

B. Measure, adjust, and record the following data for each electric heating coil:

1. Nameplate data
2. Airflow
3. Entering and leaving air temperature at full load
4. Voltage and amperage input of each phase at full load and at each incremental stage
5. Calculated kilowatt at full load
6. Fuse or circuit-breaker rating for overload protection

C. Measure, adjust, and record the following data for each refrigerant coil:

1. Dry-bulb temperature of entering and leaving air
2. Wet-bulb temperature of entering and leaving air
3. Airflow
4. Air pressure drop
5. Refrigerant suction pressure and temperature

3.16 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

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

1. Measure and record the operating speed, airflow, and static pressure of each fan.
2. Measure motor voltage and amperage. Compare the values to motor nameplate information.

3. Check the refrigerant charge.
4. Check the condition of filters.
5. Check the condition of coils.
6. Check the operation of the drain pan and condensate-drain trap.
7. Check bearings and other lubricated parts for proper lubrication.
8. Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.

B. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished. Verify the following:

1. New filters are installed.
2. Coils are clean and fins combed.
3. Drain pans are clean.
4. Fans are clean.
5. Bearings and other parts are properly lubricated.
6. Deficiencies noted in the preconstruction report are corrected.

C. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.

1. Compare the indicated airflow of the renovated work to the measured fan airflows and determine the new fan speed and the face velocity of filters and coils.
2. Verify that the indicated airflows of the renovated work result in filter and coil face velocities and fan speeds that are within the acceptable limits defined by equipment manufacturer.
3. If calculations increase or decrease the air flow rates and water flow rates by more than 5%, make equipment adjustments to achieve the calculated rates. If increase or decrease is 5% or less, equipment adjustments are not required.
4. Balance each air outlet.

3.17 TOLERANCES

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

1. Supply, Return, and Exhaust Fans and Equipment with Fans: minus 5% to plus 10%
2. Outside air: zero to plus 10%
3. VAV boxes: ± 5%
4. Air Outlets and Inlets: ± 10%
5. Pressurized rooms (positive): supply - plus 5%; exhaust/return - minus 5% (room offset tolerance plus 10%)
6. Pressurized rooms (negative): supply - minus 5%, exhaust/return - plus 5 % (room offset tolerance plus 10%)
7. Heating-Water Flow Rate: ± 5%
8. Cooling-Water Flow Rate: ± 5%

3.18 REPORTING

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

3.19 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 signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Pump curves
2. Fan curves
3. Manufacturers' test data
4. Field test reports prepared by system and equipment installers
5. Other information relative to equipment performance. Do not include Shop Drawings and product data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page
2. Name and address of the TAB contractor
3. Project name
4. Project location
5. Engineer's name and address
6. Contractor's name and address
7. Report date
8. Signature of TAB supervisor who certifies the report
9. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
10. Summary of contents including the following:
    a. Indicated versus final performance
    b. Notable characteristics of systems
    c. Description of system sequence of operation if it varies from the Contract Documents.
11. Nomenclature sheets for each item of equipment.
12. Data for terminal units, including manufacturer's name, type, size, and fittings.
13. Notes to explain why certain final data in the body of reports vary from indicated values.
14. Test conditions for fans and pump performance forms including the following:
    a. Settings for outdoor, return, and exhaust air dampers
    b. Conditions of filters
    c. Cooling coil, wet and dry-bulb conditions
    d. Face and bypass damper settings at coils.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.
    f. Inlet vane settings for variable-air-volume systems.
    g. Settings for supply air, static-pressure controller.
    h. Other system operating conditions that affect performance.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outdoor, supply, return, and exhaust airflows
2. Water and steam flow rates
3. Duct, outlet, and inlet sizes
4. Pipe and valve sizes and locations
5. Terminal units
6. Balancing stations
7. Position of balancing devices

E. Air-Handling Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data:
    a. Unit identification
    b. Location
    c. Make and type

d. Model number and unit size
e. Manufacturer's serial number
f. Unit arrangement and class
g. Discharge arrangement
h. Sheave make, size in inches, and bore
i. Center-to-center dimensions of sheave, and number of adjustments in inches
j. Number, make, and size of belts
k. Number, type, and size of filters

2. Motor Data:
a. Motor make, and frame type and size
b. Horsepower and rpm
c. Volts, phase, and hertz
d. Full-load amperage and service factor
e. Sheave make, size in inches, and bore
f. Center-to-center dimensions of sheave, and number of adjustments in inches

3. Test Data (Indicated and Actual Values):
a. Total air flow rate in cfm
b. Total system static pressure in inches wg
c. Fan rpm
d. Discharge static pressure in inches wg
e. Filter static-pressure differential in inches wg
f. Preheat coil static-pressure differential in inches wg
g. Cooling coil static-pressure differential in inches wg
h. Heating-coil static-pressure differential in inches wg
i. Outdoor airflow in cfm
j. Return airflow in cfm
k. Outdoor-air damper position
l. Return-air damper position

F. Apparatus-Coil Test Reports:

1. Coil Data:
a. System identification
b. Location
c. Coil type
d. Number of rows
e. Fin spacing in fins per inch o.c.
f. Make and model number
g. Circuiting arrangement

2. Test Data (Indicated and Actual Values):
a. Air flow rate in cfm
b. Average face velocity in fpm
c. Air pressure drop in inches wg
d. Outdoor air, wet and dry-bulb temperatures in deg F
e. Return air, wet and dry-bulb temperatures in deg F
f. Entering air, wet and dry-bulb temperatures in deg F
g. Leaving air, wet and dry-bulb temperatures in deg F
h. Water flow rate in gpm
i. Water pressure differential in feet of head or psig.
j. Entering-water temperature in deg F
k. Leaving-water temperature in deg F

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

1. Unit Data:
   a. System identification
   b. Location
   c. Coil identification
   d. Capacity in Btu/h
   e. Number of stages
   f. Connected volts, phase, and hertz
   g. Rated amperage
   h. Air flow rate in cfm
   i. Face area in sq. ft.
   j. Minimum face velocity in fpm

2. Test Data (Indicated and Actual Values):
   a. Heat output in Btu/h
   b. Air flow rate in cfm
   c. Air velocity in fpm
   d. Entering-air temperature in deg F
   e. Leaving-air temperature in deg F
   f. Voltage at each connection
   g. Amperage for each phase

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

1. Fan Data:
   a. System identification
   b. Location
   c. Make and type
   d. Model number and size
   e. Manufacturer's serial number
   f. Arrangement and class
   g. Sheave make, size in inches, and bore
   h. Center-to-center dimensions of sheave, and number of adjustments in inches

2. Motor Data:
   a. Motor make, and frame type and size
   b. Horsepower and rpm
   c. Volts, phase, and hertz
   d. Full-load amperage and service factor
   e. Sheave make, size in inches, and bore
   f. Center-to-center dimensions of sheave, and number of adjustments in inches
   g. Number, make, and size of belts

3. Test Data (Indicated and Actual Values):
   a. Total airflow rate in cfm
   b. Total system static pressure in inches wg
   c. Fan rpm
   d. Discharge static pressure in inches wg
   e. Suction static pressure in inches wg
   f. Calculate and report Fan Energy Index to verify fac complies with ASHRAE Standard 90.1

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

1. Report Data:
   a. System and air-handling-unit number
   b. Location and zone

c. Traverse air temperature in deg F
d. Duct static pressure in inches wg
e. Duct size in inches
f. Duct area in sq. ft.
g. Indicated air flow rate in cfm
h. Indicated velocity in fpm
i. Actual air flow rate in cfm
j. Actual average velocity in fpm

K. Air-Terminal-Device Reports:

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

2. Test Data (Indicated and Actual Values):
   a. Air flow rate in cfm
   b. Air velocity in fpm
   c. Preliminary air flow rate as needed in cfm
   d. Preliminary velocity as needed in fpm
   e. Final air flow rate in cfm
   f. Final velocity in fpm
   g. Space temperature in deg F

L. Terminal Unit Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:
   a. System and air-handling-unit identification
   b. Location and zone
   c. Room or riser served
   d. Coil make and size
   e. Flowmeter type

2. Test Data (Indicated and Actual Values):
   a. Air flow rate in cfm
   b. Entering-water temperature in deg F
   c. Leaving-water temperature in deg F
   d. Water pressure drop in feet of head or psig
   e. Entering-air temperature in deg F
   f. Leaving-air temperature in deg F

M. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:

1. Unit Data:
   a. Unit identification
   b. Location
   c. Service
   d. Make and size
   e. Model number and serial number
   f. Water flow rate in gpm

g. Water pressure differential in feet of head or psig
h. Required net positive suction head in feet of head or psig
i. Pump rpm
j. Impeller diameter in inches
k. Motor make and frame size
l. Motor horsepower and rpm
m. Voltage at each connection
n. Amperage for each phase
o. Full-load amperage and service factor
p. Seal type

2. Test Data (Indicated and Actual Values):
a. Static head in feet of head or psig
b. Pump shutoff pressure in feet of head or psig
c. Actual impeller size in inches
d. Full-open flow rate in gpm
e. Full-open pressure in feet of head or psig
f. Final discharge pressure in feet of head or psig
g. Final suction pressure in feet of head or psig
h. Final total pressure in feet of head or psig
i. Final water flow rate in gpm
j. Voltage at each connection
k. Amperage for each phase

N. Instrument Calibration Reports:

1. Report Data:
a. Instrument type and make
b. Serial number
c. Application
d. Dates of use
e. Dates of calibration

3.20 INSPECTIONS

A. Final Inspection:

1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by Commissioning Authority.

2. Commissioning Authority shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.

3. 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."

4. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

B. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:

1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.

2. If the second final inspection also fails, Owner may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

C. Prepare test and inspection reports.

3.21 ADDITIONAL TESTS

A. 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 230593

SECTION 230713 – DUCT INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section includes insulating the following duct services:

1. Indoor, concealed supply, return, and outdoor air.
2. Indoor, exposed supply, return, and outdoor air.
3. Outdoor, exposed supply, return, and outdoor air.

B. Related Sections:

1. Division 23 Section 230719 - “HVAC Piping Insulation.”

1.3 SUBMITTALS

A. Product Data: For each type of product indicated. Include thermal conductivity, outer surface emissivity, water-vapor permeance thickness, and jackets (both factory and field-applied when required).

B. Qualification Data: For qualified Installer.

1.4 QUALITY ASSURANCE

A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.

B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.5 DELIVERY, STORAGE, AND HANDLING

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

1.6 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Division 23 Section 230529 - "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with duct Installer for duct insulation application.

1.7 SCHEDULING

A. Schedule insulation application after pressure testing systems. Insulation application may begin on

segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," and "Aboveground, Outdoor Duct and Plenum Insulation Schedule" sections for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Flexible Elastomeric Insulation: Closed-cell, sponge, or expanded-rubber materials. Comply with ASTM C 534, Type II for sheet materials, minimum 3.0 PCF density. Not suitable for temperatures lower than -70 °F and higher than 220 °F.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Armacell LLC; AP Armaflex with field-applied jacket or Armacell ArmaTuff with factory-applied jacket.

F. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, Type III with factory-applied FSK jacket, aluminum-foil, fiberglass reinforced scrim with kraft-paper backing, complying with ASTM C 1136, Type II.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. CertainTeed Corp.; SoftTouch Duct Wrap
   b. Johns Manville; Microlite
   c. Knauf Insulation; Friendly Feel Duct Wrap
   d. Manson Insulation Inc.; Alley Wrap
   e. Owens Corning; SOFTR All-Service Duct Wrap

G. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation with factory-applied FSK jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" section.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. CertainTeed Corp.; Commercial Board
   b. Fibrex Insulations Inc.; FBX
   c. Johns Manville; 800 Series Spin-Glas
   d. Knauf Insulation; Insulation Board
   e. Manson Insulation Inc.; AK Board
   f. Owens Corning; Fiberglas 700 Series

2.2 FIRE-RELATED INSULATION SYSTEMS

A. Fire-Rated Board: Structural-grade, press-molded, xonolite calcium silicate, fireproofing board suitable for operating temperatures up to 1700 °F. Comply with ASTM C 656, Type II, Grade 6. Tested and certified to provide a 2-hour fire rating by an NRTL acceptable to authorities having jurisdiction.

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Johns Manville; Super Firetemp M

B. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with FSK jacket that is testged and certified to provide a 2-hour fire rating by an NRTL acceptable to authorities having jurisdiction.

1. Products: Subject to compliance with requirements, provide one of the following:
   a. CertainTeed Corp; FlameChek
   b. Johns Manville; Super Firetemp M
   c. 3M; Fire Barrier Wrap Products

2.3 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Aeroflex USA, Inc.; Aeroseal
   b. Armacell LLC; Armaflex 520 Adhesive
   c. Foster Brand, Specialty Construction Brands, Inc.; 85-75
   d. K-Flex USA; R-373 Contact Adhesive
   e. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2. Use adhesive that complies with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers," including 2004 Addenda.

B. ASJ Adhesive, and FSK Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc.; CP-82
   b. Eagle Bridges - Marathon Industries; 225
   c. Foster Brand, Specialty Construction Brands, Inc.; 85-50
   d. Mon-Eco Industries, Inc.; 22-25
   e. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2. Use adhesive that complies with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers," including 2004 Addenda.

C. PVC Jacket Adhesive: Compatible with PVC jacket.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Dow Corning Corporation; 739, Dow Silicone
   b. Johns Manville; Zeston Perma-Weld, CEEL-TITE Solvent Welding Adhesive
   c. P.I.C. Plastics, Inc.; Welding Adhesive

d. Speedline Corporation; Polyco VP Adhesive
e. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2. Use adhesive that complies with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers," including 2004 Addenda.

2.4 MASTICS

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

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Foster Brand, Specialty Construction Brands, Inc.; 30-80/30-90
   b. Vimasco Corporation; 749

   c. Water-Vapor Permeance: ASTM E 96, Procedure B, 0.013 perm at 43-mil dry film thickness

2. Service Temperature Range: -20 to 180°F
3. Solids Content: ASTM D 1644, 58 percent by volume and 70% by weight
4. Color: White

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

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc.; CP-30
   b. Eagle Bridges - Marathon Industries; 501
   c. Foster Brand, Specialty Construction Brands, Inc.; 30-35
   d. Mon-Eco Industries, Inc.; 55-10
   e. Water-Vapor Permeance: ASTM F 1249, 0.05 perm at 35-mil dry film thickness

2. Service Temperature Range: 0 to 180°F
3. Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight
4. Color: White

C. Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below ambient services.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc.; Encacel
   b. Eagle Bridges - Marathon Industries; 570
   c. Foster Brand, Specialty Construction Brands, Inc.; 60-95/60-96
   d. Water-Vapor Permeance: ASTM F 1249, 0.05 perm at 30-mil dry film thickness

2. Service Temperature Range: -50 to 220°F
3. Solids Content: ASTM D 1644, 33 percent by volume and 46 percent by weight
4. Color: White

D. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc.; CP-10
   b. Eagle Bridges - Marathon Industries; 550
   c. Foster Brand, Specialty Construction Brands, Inc.; 46-50

d. Mon-Eco Industries, Inc.; 55-50
e. Vimasco Corporation; WC-1/WC-5
g. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness

2. Service Temperature Range: -20 to 180°F
3. Solids Content: 60 percent by volume and 66 percent by weight
4. Color: White

2.5 LAGGING ADHESIVES

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

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc.; CP-50 AHV2
   b. Foster Brand, Specialty Construction Brands, Inc.; 30-36
   c. Vimasco Corporation; 713 and 714

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

2.6 SEALANTS

A. FSK and Metal Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc.; CP-76
   b. Eagle Bridges - Marathon Industries; 405
   c. Foster Brand, Specialty Construction Brands, Inc.; 95-44
   d. Mon-Eco Industries, Inc.; 44-05
   e. Materials shall be compatible with insulation materials, jackets, and substrates

2. Fire and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: -40 to 250°F
4. Color: Aluminum
5. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Use sealants that comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers," including 2004 Addenda.

B. ASJ Flashing Sealants, and Vinyl and PVC Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc.; CP-76
   b. Materials shall be compatible with insulation materials, jackets, and substrates.

2. Fire and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: -40 to 250°F
4. Color: White
5. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Use sealants that comply with the testing and product requirements of the California Department

of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers," including 2004 Addenda.

2.7 FIELD APPLIED JACKETS

A. Self-Adhesive Outdoor Jacket: 15.5-mil thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a cross-laminated polyethylene film covered with stucco-embossed aluminum-foil facing.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Venture Tape, 1579CW-E

2.8 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. ABI, Ideal Tape Division; 428 AWF ASJ
   b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836
   c. Compac Corporation; 104 and 105
   d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ
   e. Width: 3 inches

2. Thickness: 11.5 mil
3. Adhesion: 90 ounces force/inch in width
4. Elongation: 2 percent
5. Tensile Strength: 40 lbf/inch 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 C 1136.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. ABI, Ideal Tape Division; 491 AWF FSK
   b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827
   c. Compac Corporation; 110 and 111
   d. Venture Tape; 1525 CW NT, 1528 CW, and 1528 CW/SQ
   e. Width: 3 inches

2. Thickness: 6.5 mils
3. Adhesion: 90 ounces force/inch in width
4. Elongation: 2 percent
5. Tensile Strength: 40 lbf/inch in width
6. FSK Tape Disks and Squares: Precut disks or squares of FSK tape

2.9 SECUREMENTS

A. Bands:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. ITW Insulation Systems; Gerrard Strapping and Seals
   b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs
   c. Stainless Steel: ASTM A 167 or ASTM A 240, Type 304; 0.015 inch thick, 1/2 inch

wide with wing seal or closed seal

2. Aluminum: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 1/2 inch wide with wing seal or closed seal.
3. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.

B. Insulation Pins and Hangers:

1. Capacitor Discharge-Weld Pins: Copper or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inchdiameter shank, length to suit depth of insulation indicated.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) AGM Industries, Inc.; CWP-1
      2) GEMCO; CD.
      3) Midwest Fasteners, Inc.; CD
      4) Nelson Stud Welding; TPA, TPC, and TPS

2. Cupped-Head, Capacitor Discharge-Weld Pins: Copper or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inchdiameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) AGM Industries, Inc.; CHP-1
      2) GEMCO; Cupped Head Weld Pin
      3) Midwest Fasteners, Inc.; Cupped Head
      4) Nelson Stud Welding; CHP

3. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that can hold insulation, of thickness indicated, securely in position indicated when self-locking washer is in place.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) AGM Industries, Inc.; Tactoo Perforated Base Insul-Hangers
      2) GEMCO; Perforated Base
      3) Midwest Fasteners, Inc.; Spindle

   b. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
   c. Spindle: Copper or zinc-coated, low-carbon steel, aluminum, stainless steel, fully annealed, 0.106-inch diameter shank, length to suit depth of insulation indicated.
   d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers and substrates.

4. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that can hold insulation, of thickness indicated, securely in position indicated when self-locking washer is in place.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) AGM Industries, Inc.; Tactoo Self-Adhering Insul-Hangers
      2) GEMCO; Peel & Press
      3) Midwest Fasteners, Inc.; Self Stick

   b. Baseplate: Galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
   c. Spindle: Copper or zinc-coated, low-carbon steel, aluminum, stainless steel, fully annealed, 0.106-inch diameter shank, length to suit depth of insulation indicated.
   d. Adhesive-backed base with a peel-off protective cover.

5. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch thick, galvanized-steel, aluminum, or stainless-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) AGM Industries, Inc.; RC-150
      2) GEMCO; R-150
      3) Midwest Fasteners, Inc.; WA-150
      4) Nelson Stud Welding; Speed Clips

   b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

6. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
   a. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
      1) GEMCO
      2) Midwest Fasteners, Inc

C. Staples: Outward-clinching insulation staples, nominal 3/4-inch wide, stainless steel or Monel.

D. Wire: 0.080-inch nickel-copper alloy, 0.062-inch soft-annealed, stainless steel or 0.062-inch soft-annealed, galvanized steel.

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   a. C & F Wire

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces, free of voids throughout the length of ducts and fittings.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Keep insulation materials dry during storage, application, and finishing.

G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

H. Install insulation with least number of joints practical.

I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

K. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.
2. Cover circumferential joints with 3-inch-wide strips of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.
   a. For below-ambient services, apply vapor-barrier mastic over staples.
4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

L. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

3.4 PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
4. Seal jacket to wall flashing with flashing sealant.

C. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

D. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches.

1. Comply with requirements in Division 7 Section "Penetration Firestopping" for firestopping and fire-resistive joint sealers.

E. Insulation Installation at Floor Penetrations:

1. Duct: For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches.
2. Seal penetrations through fire-rated assemblies. Comply with requirements in Division 7 Section "Penetration Firestopping."

3.5 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

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

3.6 INSTALLATION OF MINERAL FIBER INSULATION

A. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge weld pins and speed washer or cupped-head, capacitor-discharge weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
    a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
    b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
    c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
    d. Do not over compress insulation during installation.
    e. Impale insulation over pins and attach speed washers.
    f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
    g. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1-inch o.c. Install vapor barrier consisting of factory or field-applied jacket, adhesive, vapor-barrier

mastic, and sealant at joints, seams, and protrusions.

h. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.

i. Install vapor stops for ductwork and plenums operating below 50°F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

j. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.

4. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

5. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

B. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

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

2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.

3. Install either capacitor-discharge weld pins and speed washer or cupped-head, capacitor-discharge weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.

b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.

c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.

d. Do not over compress insulation during installation.

e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

f. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1-inch o.c. Install vapor barrier consisting of factory or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

g. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.

h. Install vapor stops for ductwork and plenums operating below 50°F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

i. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

5. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.7 FIELD APPLIED JACKET INSTALLATION

A. Where jackets are indicated, install as follows:

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

3.8 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Perform tests and inspections.

C. Tests and Inspections:

1. Inspect ductwork, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location for each duct system defined in the "Duct Insulation Schedule, General" Article.

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

3.9 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation:

1. Indoor, concealed supply, return, and outdoor air.
2. Indoor, exposed supply and outdoor air.
3. Outdoor, exposed outdoor air supply.

B. Items Not Insulated:

1. Fibrous-glass ducts.
2. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
3. Factory-insulated flexible ducts.
4. Factory-insulated plenums and casings.
5. Flexible connectors.
6. Vibration-control devices.
7. Factory-insulated access panels and doors.

3.10 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Concealed (installed above ceilings), rectangular, round, and flat-oval supply air duct insulation shall be mineral-fiber blanket, 2 inches thick and 1.5 PCF nominal density.

B. Exposed, rectangular, round, and flat-oval supply air duct insulation shall be flexible elastomeric, 1 inch thick, black.

C. Return Air Ducts, Concealed (installed above ceilings):

1. 1” thick fiberglass duct liner.

D. Exposed Supply and Return Ductwork in Air Conditioned, Occupied Spaces, and Exhaust Air Ductwork:

1. None.

E. Exposed Supply and Return Ductwork exposed in Air-Conditioned Utility Spaces (Conditioned

Mechanical Rooms or Mechanical Rooms used as Return Air Plenums) and Exposed in Non-Air-Conditioned Spaces (Boiler Rooms, et. al):

1. Mineral-Fiber Board Insulation: 2 inches thick and installed R-6.0

F. Outside-Air Ducts:

1. Mineral-Fiber Blanket: 2 inches thick and installed R-6.0

G. Type-I Commercial Kitchen Hood Exhaust Ducts:

1. None

H. Type-II Commercial Kitchen Hood and Dishwasher Exhaust Ducts:

1. None

I. Kitchen Hood Make-Up Air Ducts:

1. Mineral-Fiber Blanket: 2 inches thick and installed R-5.0

3.11 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. Ducts, Plenums, and Piping, Concealed (installed above ceilings) and Exposed in Air-Conditioned Occupied Spaces:

1. None.

D. Ducts, Plenums, and Piping, Exposed in Air-Conditioned Utility Spaces (Conditioned Mechanical Rooms and Mechanical Rooms used as Return Air Plenums):

1. 8-ounce canvas with lagging adhesive.

E. Ducts, Plenums, and Piping, Exposed in Non-Air-Conditioned Spaces (Boiler Rooms, et. al.):

1. PVC: 20 mils thick (N/A if installed in a return air plenum)
2. Aluminum, Smooth: 0.016 inch thick

F. Equipment, Concealed (installed above ceilings):

1. None

END OF 230713

SECTION 230719 –HVAC PIPING INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section includes insulating the following HVAC piping systems:

1. Chilled water piping insulation.
2. Hot water piping insulation.

1.3 ACCEPTABLE MANUFACTURERS

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

1. Armacell, Armaflex Microban (Owner preferred)
2. Aeroflex
3. Certain Teed Corp
4. Johns Manville
5. Knauf Insulation
6. Owens Corning
7. Pittsburg Corning Corp.
8. Dyplast Products

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include thermal conductivity, outer surface emissivity, water-vapor permeance thickness, and jackets (both factory and field applied if any).

1.5 QUALITY ASSURANCE

A. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.6 DELIVERY, STORAGE, AND HANDLING

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

1.7 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with piping Installer for piping insulation application. Coordinate installation and testing of heat tracing.

1.8 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," and "Outdoor, Aboveground Piping Insulation Schedule" sections for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" section.

1. Block Insulation: ASTM C 552, Type I
2. Special-Shaped Insulation: ASTM C 552, Type III
3. Board Insulation: ASTM C 552, Type IV
4. Preformed Pipe Insulation without Jacket: Comply with ASTM C 552, Type II, Class 1
5. Preformed Pipe Insulation with Factory-Applied [ASJ] [ASJ-SSL]: Comply with ASTM C 552, Type II, Class 2.
6. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.

G. Flexible Elastomeric Insulation: Closed-cell materials. Comply with ASTM C 534, Type I for tubular materials. Not suitable for temperatures lower than -70°F and higher than 220°F.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Armacell LLC; AP Armaflex with field-applied jacket or Armacell ArmaTuff with factory-applied jacket.

H. Mineral-Fiber, Preformed Pipe Insulation:

1. Type I, 850°F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

I. Mineral-Fiber, Pipe Insulation Wicking System: Preformed pipe insulation complying with ASTM C 547, Type I, Grade A, with absorbent cloth factory applied to the entire inside surface of preformed pipe insulation and extended through the longitudinal joint to outside surface of insulation under insulation jacket. Factory apply a white, polymer, vapor-retarder jacket with self-sealing adhesive tape seam and evaporation holes running continuously along the longitudinal seam, exposing the absorbent

cloth.

J. Polyolefin: Unicellular, polyethylene thermal plastic insulation. Comply with ASTM C 534 or ASTM C 1427, Type I, Grade 1 for tubular materials and Type II, Grade 1 for sheet materials.

K. Phenolic:

1. Preformed pipe insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type III, Grade 1.
2. Block insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type II, Grade 1.
3. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.
4. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.
   a. Preformed Pipe Insulation: ASJ
   b. Board for Duct and Plenum Applications: ASJ
   c. Board for Equipment Applications: ASJ

2.2 INSULATING CEMENTS

A. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C 196.

2.3 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Cellular-Glass Adhesive: Two component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of -100 to 200°F.

1. Products: Subject to compliance with requirements, provide the following:
   a. Foster Brand, Specialty Construction Brands, Inc.; 81-84.

2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.

1. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

D. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

1. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

E. ASJ Adhesive, and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

1. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various

Sources Using Small-Scale Environmental Chambers."

F. PVC Jacket Adhesive: Compatible with PVC jacket.

1. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.4 MASTICS

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

1. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
2. Service Temperature Range: -20 to 180°F
3. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
4. Color: White

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

1. Water-Vapor Permeance: ASTM F 1249, 0.05 perm at 30-mil dry film thickness.
2. Service Temperature Range: -50 to 220°F

D. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.

1. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
2. Service Temperature Range: -20 to 180°F
3. Solids Content: 60 percent by volume and 66 percent by weight.
4. Color: White

2.5 LAGGING ADHESIVES

A. Lagging Adhesives:

1. For indoor applications, use lagging adhesives that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.
3. Service Temperature Range: 0 to 180°F
4. Color: White

2.6 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass, Phenolic, and Polyisocyanurate Products: Subject to compliance with requirements, provide one of the following:
   a. Childers Brand, Specialty Construction Brands, Inc.; CP-76
   b. Eagle Bridges - Marathon Industries; 405
   c. Foster Brand, Specialty Construction Brands, Inc.; 30-45
   d. Mon-Eco Industries, Inc.; 44-05
   e. Pittsburgh Corning Corporation; Pittseal 444

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Permanently flexible, elastomeric sealant.
4. Service Temperature Range: -100 to 300°F

5. Color: White or gray
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. FSK and Metal Jacket Flashing Sealants:

1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: -40 to 250°F
4. Color: Aluminum
5. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Fire and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: -40 to 250°F
4. Color: White
5. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

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 C 1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
5. PVDC Jacket for Indoor Applications: 4-mil-thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perm when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.
6. PVDC Jacket for Outdoor Applications: 6-mil-thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perm when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.
7. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.
8. Vinyl Jacket: White vinyl with a permeance of 1.3 perms when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.8 FIELD APPLIED FABRIC REINFORCING MESH

A. Woven Glass-Fiber Fabric: Approximately 2 oz. / sq. yd. with a thread count of 10 strands by 10 strands/sq. in. for covering pipe and pipe fittings.

B. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq.in., in a Leno weave, for pipe.

2.9 FIELD APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd.

2.10 FIELD APPLIED JACKETS

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

B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.

1. Adhesive: As recommended by jacket material manufacturer.
2. Color: Color-code jackets based on system. Color as selected by Architect.
3. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.
    a. Shapes: 45 and 90-degree, short and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

D. Metal Jacket:

1. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.
    a. Sheet and roll stock ready for shop or field sizing.
    b. Finish and thickness are indicated in field-applied jacket schedules.
    c. Moisture Barrier for Indoor Applications: 3-mil-thick, heat-bonded polyethylene and kraft paper; or 2.5-mil-thick polysurlyn
    d. Moisture Barrier for Outdoor Applications: 3-mil-thick, heat-bonded polyethylene and kraft paper; or 2.5-mil-thick polysurlyn
    e. Factory-Fabricated Fitting Covers:
        1) Same material, finish, and thickness as jacket.
        2) Preformed 2-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 cover
        8) Field fabricate fitting cover only if factory-fabricated fitting covers are not available.

2.11 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

1. Width: 3 inches
2. Thickness: 11.5 mils
3. Adhesion: 90 ounces force/inch in width
4. Elongation: 2 percent

5. Tensile Strength: 40 lbf/inch 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 C 1136.

1. Width: 3 inches
2. Thickness: 6.5 mils
3. Adhesion: 90 ounces force/inch in width
4. Elongation: 2 percent
5. Tensile Strength: 40 lbf/inch in width
6. FSK Tape Disks and Squares: Precut disks or squares of FSK tape

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.

1. Width: 2 inches
2. Thickness: 6 mils
3. Adhesion: 64 ounces force/inch in width
4. Elongation: 500 percent
5. Tensile Strength: 18 lbf/inch in width

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. Width: 2 inches
2. Thickness: 3.7 mils
3. Adhesion: 100 ounces force/inch in width
4. Elongation: 5 percent
5. Tensile Strength: 34 lbf/inch in width

E. PVDC Tape for Indoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

1. Width: 3 inches
2. Film Thickness: 4 mils
3. Adhesive Thickness: 1.5 mils
4. Elongation at Break: 145 percent
5. Tensile Strength: 55 lbf/inch in width

F. PVDC Tape for Outdoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.

1. Width: 3 inches
2. Film Thickness: 6 mils
3. Adhesive Thickness: 1.5 mils
4. Elongation at Break: 145 percent
5. Tensile Strength: 55 lbf/inch in width

2.12 SECUREMENTS

A. Bands:

1. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304; 0.015 inch thick, 1/2 inch wide with wing seal.
2. Aluminum: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 3/4 inch wide with wing seal.
3. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.

B. Staples: Outward-clinching insulation staples, nominal 3/4-inch-wide, stainless steel, or Monel.

C. Wire: 0.080-inch 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.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

B. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.

C. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping including fittings, valves, and specialties.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of pipe system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

G. Keep insulation materials dry during application and finishing.

H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

I. Install insulation with least number of joints practical.

J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket,

arranged to protect jacket from tear or puncture by hanger, support, and shield.

K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

L. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.
2. Cover circumferential joints with 3-inch-wide strips of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.
   a. For below-ambient services, apply vapor-barrier mastic over staples.
4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

M. Cut insulation in a manner to avoid compressing insulation more than 75% of its nominal thickness.

N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

P. For above-ambient services, do not install insulation to the following:

1. Vibration-control devices
2. Testing agency labels and stamps
3. Nameplates and data plates
4. Manholes
5. Handholes
6. Cleanouts

3.4 PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.

3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
4. Seal jacket to wall flashing with flashing sealant.

D. Insulation Installation at Interior Wall and Partition Penetrations (non-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.

F. Insulation Installation at Floor Penetrations:

1. Pipe: Install insulation continuously through floor penetrations.
2. Seal penetrations through fire-rated assemblies.

3.5 GENERAL PIPE INSULATION INSTALLATION

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

B. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:

1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
   a. Install preformed removable insulation over all control valve bodies with water resistant, attached reusable fasteners. Insulation assembly and fasteners shall be suitable for the environment and will not impede the operation of the valve or block visual sight of the actuator indicator.

2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.
6. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
8. For services not specified to receive a field-applied jacket except for flexible elastomeric

and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.

9. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

D. Install removable insulation covers at locations indicated. Installation shall conform to the following:

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

3.6 INSTALLATION OF CELLULAR GLASS INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

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

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as pipe insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When preformed sections of insulation are not available, install mitered sections of cellular-glass insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of cellular-glass insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.7 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 pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

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

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed valve covers manufactured of same material as pipe insulation when available.
2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.8 MINERAL FIBER INSULATION INSTALLATION

A. Insulation Installation on Straight Pipes and Tubes:

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

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

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

D. Insulation Installation on Valves and Pipe Specialties:

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

3.9 PHENOLIC INSULATION INSTALLATION

A. General Installation Requirements:

1. Secure single-layer insulation with stainless-steel bands at 12-inch intervals and tighten bands without deforming insulation materials.
2. Install 2-layer insulation with joints tightly butted and staggered at least 3 inches. Secure inner layer with 0.062-inch wire spaced at 12-inch intervals. Secure outer layer with stainless-steel bands at 12-inch intervals.

B. Insulation Installation on Straight Pipes and Tubes:

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

C. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as pipe insulation.

D. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed insulation sections of same material as straight segments of pipe insulation.

Secure according to manufacturer's written instructions.

E. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed insulation sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.10 FIELD APPLIED JACKET INSTALLATION

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

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

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

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

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

1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.

D. Where metal jackets are indicated, install with 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 12 inches o.c. and at end joints.

E. Where PVDC jackets are indicated, install as follows:

1. Apply three separate wraps of filament tape per insulation section to secure pipe insulation to pipe prior to installation of PVDC jacket.
2. Wrap factory pre-sized jackets around individual pipe insulation sections with one end overlapping the previously installed sheet. Install pre-sized jacket with an approximate overlap at butt joint of 2 inches over the previous section. Adhere lap seal using adhesive or SSL, and then apply 1-1/4 circumferences of appropriate PVDC tape around overlapped butt joint.
3. Continuous jacket can be spiral-wrapped around a length of pipe insulation. Apply adhesive or PVDC tape at overlapped spiral edge. When electing to use adhesives, refer to manufacturer's written instructions for application of adhesives along this spiral edge to maintain a permanent bond.
4. Jacket can be wrapped in cigarette fashion along length of roll for insulation systems with an outer circumference of 33-1/2 inches or less. The 33-1/2-inch-circumference limit allows for 2-inch-overlap seal. Using the length of roll allows for longer sections of jacket to be installed at one time. Use adhesive on the lap seal. Visually inspect lap seal for "fish-mouthing," and use PVDC tape along lap seal to secure joint.
5. Repair holes or tears in PVDC jacket by placing PVDC tape over the hole or tear and wrapping a

minimum of 1-1/4 circumferences to avoid damage to tape edges.

3.11 FINISHES

A. Pipe Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below.

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. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Perform tests and inspections.

C. Tests and Inspections:

1. Inspect pipe, fittings, strainers, and valves, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be 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" section.

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

3.13 PIPING INSULATION SCHEDULE, GENERAL

A. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.

B. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:

1. Drainage piping located in crawl spaces.
2. Underground piping.
3. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

3.14 INDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water below 60 °F:

1. All Pipe Sizes: Insulation shall be one of the following:
   a. Flexible Elastomeric: 1” thick
   b. Polyolefin: 1” Chilled Water

B. Chilled Water Supply & Return NPS 14 and Smaller: Insulation shall be one of the following:
   a. Cellular Glass: 2” thick

b. Flexible Elastomeric: 2” thick
c. Polyolefin: 1-1/2” thick
d. Phenolic: 1-1/2” thick

C. Heating Hot Water Supply and Return, 200 °F and Below:

1. NPS 1-1/2” and Smaller: Insulation shall be one of the following:
   a. Flexible Elastomeric: 2” thick
   b. Polyolefin: 1-1/2” thick
   c. Cellular Glass: 2” thick
   d. Mineral-Fiber, Preformed Pipe, Type I: 1-1/2” thick

2. NPS 2” and Larger: Insulation shall be one of the following:
   a. Flexible Elastomeric: 2” thick
   b. Polyolefin: 2” thick
   c. Cellular Glass: 2” thick
   d. Mineral-Fiber, Preformed Pipe, Type I: 2” thick

3.15 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

A. Chilled Water:

1. All Pipe Sizes: Insulation shall be one of the following:
   a. Cellular Glass: 3” thick
   b. Flexible Elastomeric: 3” thick
   c. Polyolefin: 3” thick
   d. Phenolic: 1-1/2” thick

3.16 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. Piping, Exposed:

1. Aluminum, Smooth 0.024” thick

3.17 OUTDOOR FIED-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. Piping, Exposed:

1. Aluminum, Smooth 0.024” thick

END OF 230719

SECTION 230800 – COMMISSIONING OF HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section includes commissioning process requirements for HVAC systems, assemblies, and equipment.

1.3 DEFINITIONS

A. Commissioning (Cx): Commissioning is a comprehensive and systematic process to verify that the building systems perform as designed to meet the Owner's requirements. Commissioning during the construction, acceptance and warranty phases is intended to achieve the following specific objectives:

1. Verify and document that the equipment is installed and started per manufacturer's recommendations, industry accepted minimum standards, and the Contract Documents.
2. Verify and document that the equipment and systems receive complete operational checkout by installing contractors.
3. Verify and document equipment and system performance.
4. Verify the completeness of the Operations and Maintenance materials.
5. Ensure that the Owner's operating personnel are adequately trained on the operation and maintenance of building equipment.
6. The commissioning process does not take away from or reduce the responsibility of the systems designers or installing contractors to provide a finished and fully functioning product.

B. Commissioning Authority (CxA): The commissioning authority develops the functional test procedures in a sequential written form, coordinates, oversees, and documents the actual testing, which is usually performed by the installing contractor or vendor. Functional Performance Tests are performed after pre-functional checklists and startup is complete.

C. Commissioning Plan (Cx Plan): A document that outlines the organization, schedule, allocation of resources, and documentation requirements of the commissioning process.

D. Deficiency: A deficiency is a condition in the installation or function of a component, piece of equipment, or system that is not in compliance with the Contract Documents or does not perform properly.

E. Functional Performance Test (FPT): The FPT is a test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods. Functional testing is the dynamic testing of systems (rather than just components) under full operation. Systems are tested under various modes, such as during low cooling or heating loads, high loads, component failure, unoccupied, varying outside air temperatures, fire alarm power failure, and any other operational sequence included in the system design. The systems are run through all the control system's sequences of operation and components are verified to be responding as the sequences state. Traditional air or water test and balancing (TAB) is not functional testing, in the commissioning sense of the word. TAB's primary work is setting up the system flows, and pressures as specified, while functional testing is verifying that which has already been set up. The CxA develops the functional test procedures in a sequential written form, coordinates, oversees and documents the actual testing, which is usually performed by the installing contractor or vendor. Functional Performance Tests are performed after pre-functional checklists and startup is complete.

F. Pre-Functional Checklist (PFC): The pre-functional checklist is a list of items to inspect and elementary component tests to verify proper installation of equipment, provided by the CxA to the contractor. PFC's are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., belt tension, oil levels OK, labels affixed, gages in place, sensors calibrated, etc.). However, some PFC items entail system testing of the function of a component, a piece of equipment or system (e.g., measuring the voltage imbalance on a three-phase pump motor of a chiller system). The word "pre-functional" refers to before functional testing. Pre-functional checklists augment, and are combined with, the manufacturer's start-up checklist.

G. HVAC: Heating, Ventilating, and Air Conditioning

H. Systems, Subsystems, Equipment, and Components: Where these terms are used together or separately, they shall mean "as-built" systems, subsystems, equipment, and components.

1.4 DESCRIPTION

A. The following equipment and/or accessories shall be commissioned as part of this project:

1. Chilled water systems and equipment
2. Hydronic hot water heating systems equipment
3. Dual temperature water system
4. Air handling units
5. Terminal HVAC equipment
6. Exhaust and Supply fans
7. Lighting control system
8. Building automation system
9. Interface connections with the BAS
10. Air purification systems

1.5 SUBMITTALS

A. Certificates of completion of installation, prestart, and startup activities.

B. CxA shall prepare Cx meeting minutes and distribute to Owner's project manager and contractors.

C. Cx Plan shall be updated as necessary during the work to reflect approved changes. CxA shall distribute to Owner's project manager and contractors.

D. Pre-Functional Checklists shall be submitted no later than thirty (30) calendar days prior to testing.

E. Functional Performance Test Forms shall be submitted no later than thirty (30) calendar days prior to testing, or two (2) weeks after acceptance of controls submittal.

F. Issues Log: CxA shall document on an Issues Log items of non-compliance in materials, installation, or operation from start-up/pre-functional checklists, functional performance testing, and on-site observations. Include details of the components or systems found to be non-compliant with the drawings, specifications, and approved submittals.

1. Update as necessary during the work to reflect the progress on the components and systems.

G. Final Cx Report: Compile a final commissioning report summarizing all the tasks, findings, conclusions, and recommendations of the commissioning process. Indicate the actual performance of the building systems in reference to the contract documents. Include completed pre-functional inspection checklists, startup reports, TAB reports, functional performance testing records, Issues Log, and a summary of commissioning activities.

1.6 CxA's RESPONSIBILITIES

A. Commissioning Authority (CxA) shall provide overall coordination and management of the commissioning program as specified herein.

B. Review design documents to verify that each commissioned system meets the Project Requirements.

C. Review construction documents to verify that commissioning is adequately specified, that each commissioned system can be commissioned and is likely to meet the Project Requirements.

D. Progress Meetings: Attend construction job-site meetings, as necessary, to monitor construction and commissioning progress. Coordinate with contractor(s) to address coordination, deficiency resolution, and planning issues.

1. Plan and coordinate additional meetings as needed based on work progress.

E. Site Observations: Perform site visits as necessary to observe component and system installations.

F. Functional Testing Coordination:

1. Equipment shall not be "temporarily" started for commissioning.
2. Functional performance testing shall not begin until pre-functional check, start-up, and TAB are completed for a given system.
3. The controls system and equipment controls shall not be functionally tested until all points have been calibrated and pre-functional checklists are complete.

1.7 CONTRACTOR RESPONSIBILITIES

A. Perform commissioning tests at the direction of the CxA.

B. Attend construction phase controls coordination meeting.

C. Attend TAB review and coordination meeting.

D. Provide information requested by the CxA for final commissioning documentation.

E. Provide measuring instruments to record test data and provide data acquisition equipment to record data for the complete range of testing for the required test period.

F. Promptly correct work rejected by the CxA or failing to conform to the requirements of the Contract Documents, whether discovered before or after Substantial Completion and whether fabricated, installed or completed or not. Costs of correcting such rejected work, including additional testing and inspections and compensation for the CxA's services and expenses made necessary thereby, shall be at the Contractor's expense.

1.8 COMMISSIONING DOCUMENTATION

A. The CxA will prepare PFC's and FPT's for all commissioned components, equipment, and systems.

B. Mechanical and Controls Contractors to provide the following information to the CxA:

1. Submittals, systems manuals, and other documents and reports.
2. Certificate of readiness certifying that HVAC systems, subsystems, equipment, and associated controls are ready for testing.
3. Certificate of completion certifying that pre-functional checks, and startup procedures have been completed.
4. Test and inspection reports and certificates.
5. Completed TAB reports.

PART 2 – PRODUCTS

2.1 TEST EQUIPMENT

A. The contractor(s) shall make available standard testing equipment required to perform pre-functional testing, startup, and functional performance testing, as well as any special tools and instruments (available from vendor, specific to a piece of equipment) required for testing equipment according to the Contract Documents.

B. Data logging equipment and software required to test equipment shall be provided by the CxA but shall not become property of the Owner.

C. Instrumentation shall meet the following standards:

1. Be of sufficient quality and accuracy to test and measure system performance within the tolerances required to determine adequate performance.
2. Be maintained and in good repair and operational condition throughout the duration of use on this project.
3. Calibration Requirements: Contractor shall comply with the test equipment manufacturer's calibration procedures and intervals. Recalibrate test instruments immediately after instruments have been repaired after being dropped or damaged. Affix calibration tags to test instruments. Furnish calibration records to CxA upon request.

PART 3 - EXECUTION

3.1 TESTING PREPARATION

A. Certify in writing to the CxA that HVAC systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents.

B. Certify in writing to the CxA that HVAC instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.

C. Certify in writing to the CxA that testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing reports have been submitted, discrepancies corrected, and corrective work approved.

D. Place systems, subsystems, and equipment into operating mode to be tested (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

E. Inspect and verify the position of each device and interlock identified on checklists.

F. Check safety cutouts, alarms, and interlocks with smoke control and life-safety systems during each mode of operation.

G. Testing Instrumentation: Install measuring instruments and logging devices to record test data as directed by the CxA.

3.2 TESTING AND BALANCING (TAB) VERIFICATION

A. Prior to performance of TAB work, provide copies of reports, sample forms, checklists, and certificates to the CxA.

B. Notify the CxA at least 10 days in advance of TAB work and provide access for the CxA to witness testing and balancing work.

C. Provide technicians, instrumentation, and tools to verify TAB of HVAC systems at the direction of the CxA.

1. The CxA will notify the TAB Contractor 10 days in advance of the date of field verification. Notice will not include data points to be verified.
2. The TAB Contractor shall use the same instruments (by model and serial number) that were used when original data were collected.
3. Failure of an item includes, other than sound, a deviation of more ±10%. Failure of more than 10% of selected items shall result in rejection of final TAB report.
4. TAB Contractor shall remedy the deficiency and notify the CxA so verification of failed portions can be performed.

3.3 GENERAL TESTING REQUIREMENTS

A. Provide technicians, instrumentation, and tools to perform commissioning test at the direction of the CxA.

B. All testing of the controls shall be from the front-end system, (i.e., the testing agency and commissioning agent shall only have access to the school being tested).

C. Scope of HVAC testing shall include entire HVAC installation, from central equipment through distribution systems to each conditioned space. Testing shall include measuring capacities and effectiveness of operational and control functions.

D. Test all operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and verify proper response of building automation system controllers and sensors.

E. The CxA shall prepare detailed testing plans, procedures, and checklists for HVAC systems, subsystems, and equipment.

F. Tests will be performed using design conditions whenever possible.

G. Simulated conditions may need to be imposed using an artificial load when it is not practical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by the CxA and document simulated conditions and methods of simulation. After tests, return settings to normal operating conditions.

H. The CxA may direct that set points be altered when simulating conditions is not practical.

I. The CxA may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are not practical.

J. If tests cannot be completed because of a deficiency outside the scope of the HVAC system, document the deficiency and report it to the Owner. After deficiencies are resolved, reschedule tests.

K. If the testing plan indicates specific seasonal testing, complete appropriate initial performance tests and documentation and schedule seasonal tests.

3.4 HVAC SYSTEMS, SUBSYSTEMS, AND EQUIPMENT TESTING PROCEDURES

A. Procedures: Where applicable follow manufacturer’s written procedures. If no procedures are prescribed by the manufacturer, proceed as follows:

1. HVAC Piping Distribution Systems: Includes chilled water and hot water heating piping systems.
   a. Verify that all valves and accessories have been installed correctly, are accessible and operate as intended.
   b. Verify that specified leak tests of piping systems are complete.

2. HVAC Air Distribution Systems: Includes supply, return, outside air general exhaust, and miscellaneous exhaust duct systems.
   a. Verify that all ductwork, air devices, terminal units and accessories have been installed correctly, are accessible and operate as intended.
   b. Verify that specified leak tests of duct systems are complete.

3. HVAC Electric Air Purification Systems
   a. Verify that Air Purification Unit is energized when associated fan is operating.
      1) CxA not responsible for performance, efficacy, or safety of Air Purification Systems.

4. HVAC Equipment: Includes air handlers, pumps, and exhaust fans.
   b. Verify that all equipment has been installed in accordance with the manufactures recommendations and all equipment can be easily accessed for maintenance.
   c. Verify that all valves, trim, fittings, controls, and accessories have been installed correctly and operates as intended.
   d. Verify that all required interfaces with the BAS have been installed correctly and operates as intended.
   e. Operate equipment as intended to ensure the design conditions can be obtained.

5. HVAC Building Automation System:
   a. Verify that all control hardware and software, sequences of operations, and integration of factory controls has been installed correctly and operates as intended.
   b. Verify that all control valves, trim, fittings, and accessories have been installed correctly and operates as intended.
   c. Verify that all equipment test, training, and startup procedures have been completed per the specifications.
   d. Verify that all required interfaces between the BAS and HVAC equipment have been installed correctly and operates as intended.
   e. Verify that all control graphics and programming has been installed in accordance with the manufacturer's recommendations and operates as intended.
   f. Operate equipment as intended to ensure the design conditions can be obtained.

B. Pipe system cleaning, flushing, hydrostatic tests, and chemical treatment requirements are specified in HVAC piping Sections. Mechanical Contractor shall prepare a pipe system cleaning, flushing, and hydrostatic testing plan. Provide cleaning, flushing, testing, and treating plan and final reports to the CxA. Plan shall include the following:

1. Sequence of testing and testing procedures for each section of pipe to be tested, identified by pipe zone or sector identification marker. Markers shall be keyed to Drawings for each pipe sector, showing the physical location of each designated pipe test section. Drawings keyed to pipe zones or sectors shall be formatted to allow each section of piping to be physically located and identified when referred to in pipe system cleaning, flushing, hydrostatic testing, and chemical treatment plan.
2. Description of equipment for flushing operations.
3. Minimum flushing water velocity.
4. Tracking checklist for managing and ensuring that all pipe sections have been cleaned, flushed, hydrostatically tested, and chemically treated.

END OF 230800

SECTION 230900 – ENERGY MANAGEMENT SYSTEM AND BUILDING AUTOMATION SYSTEM FOR HVAC AND LIGHTING CONTROL

PART 1 - GENERAL

1.1 INSTRUCTIONS TO VENDORS

A. Vendor is cautioned that the Owner reserves the right to reject any Vendor, which in the Owner's sole judgment, takes meaningful deviation or exception to Division 23 Direct Digital Control (DDC) Standards. The Charlotte-Mecklenburg Schools' (CMS) Energy Manager and/or designated representative of the Energy Management Department (EMD) shall review all vendor substitution submittals. Vendor substitution approval/disapproval shall be returned via the project architect in writing from Charlotte-Mecklenburg Schools' Energy Manager and designated EMD Project Manager.

B. The overriding requirement is the use of the DDC Control System to maintain design occupant comfort with optimal minimized energy consumption while maximizing equipment, component, and system design function integrity and life.

1.2 RELATED DOCUMENTS

A. Sections within Division 23 Mechanical apply, including though not limited to:

1. 230800 – Commissioning of HVAC
2. 230901 – Building Automation System Graphical User Interface
3. 230902 – BAS Point Naming and Tagging Guideline
4. 234320 – Air Purification System

1.3 SUMMARY

A. This Section includes Energy Management and Building Automation Systems for HVAC and Lighting control systems and components, including control components for terminal heating and cooling units and approved integration with factory-wired controls. The work of this section 230900 shall be provided by the Building Automation Systems (BAS) controls contractor.

B. The BAS controls shall be comprised of a Direct Digital Control (DDC) network of interoperable, stand-alone digital controllers communicating on a BACnet communication network over IP across the CMS network to CMS owned virtual server hosting the Web Supervisor(s).

C. The system shall provide the Direct Digital Control (DDC), Energy Management and Building Automation System (BAS) for the HVAC systems and shall interface with other microprocessor-based building subsystems as shown on the drawings and as specified.

1.4 ABBREVIATIONS AND ACRONYMS

A. AHU: Air Handling Unit

B. AI: Analog Input

C. ANSI: American National Standards Institute

D. AO: Analog Output

E. ASC: Application Specific Controller

F. ASHRAE: American Society of Heating, Refrigerating, and Air Conditioning Engineers

G. AV: Analog Value

H. AWG: American Wire Gauge (Standard)

I. BACnet/IP, BACnet/MSTP: Acceptable Communication Protocols across the EMS/BAS Controls Network

J. BAS: Building Automation System

K. BI: Binary Input

L. BO: Binary Output

M. BV: Binary Value

N. DDC: Direct Digital Controls

O. DI: Discrete Input

P. DMZ: Demilitarized Zone Network

Q. DO: Discrete Output

R. EMS/BAS: Energy Management System / Building Automation System

S. GUI: Graphical User Interface

T. HTML5: Hyper Text Markup Language 5

U. HVAC: Heating Ventilating and Air Conditioning

V. I/O: Input/output.

W. IP: Internet Protocol

X. LAN: Local Area Network

Y. MS/TP: Master Slave/Token Passing

Z. NEC: National Electric Code

AA. NPBI: Needle Point Bipolar Ionization

BB. OS: Operating System

CC. PID: Proportional Integral Derivative

DD. UL: Underwriters Laboratory

EE. VAV: Variable Air Volume

FF. VFD: Variable Frequency Drive

1.5 DEFINITIONS

A. BACnet: An industry standard data communication protocol for Building Automation and Control Networks. Refer to the latest version of AHSRAE Standard 135.

B. Scope Terminology

1. Provide = Furnish equipment, engineer, program, and install
2. Furnish = Furnish equipment, engineer, and program
3. Mount = securely fasten or pipe
4. Install = mount and wire
5. Wire = wire only

1.6 WORK INCLUDED

A. The BAS Contractor shall provide a complete and operational system that will perform the sequences of operation specified herein and on the Construction Documents.

B. Furnish a complete distributed DDC system in accordance with this specification section. This includes all system controllers, logic controllers, and all input/output devices. Items of work included are as follows:

1. Provide a submittal that meets the requirements below for approval.
2. Coordinate installation schedule with the mechanical contractor and general contractor.
3. Provide installation of all panels and devices unless otherwise stated.
4. Provide power for panels and control devices unless otherwise stated.
5. Provide all low voltage control wiring for the DDC system.
6. Provide miscellaneous control wiring for HVAC and related systems regardless of voltage.
7. Provide engineering and technician labor to program and commission software for each system and operator interface. Submit commissioning reports for approval.
8. Participate in commissioning for all equipment that is integrated into the BAS.
9. Provide testing, demonstration and training as specified below.

C. The installation of the control system shall be performed under the direct supervision of the controls manufacturer with the shop drawings, flow diagrams, bill of materials, component designation, or identification number and sequence of operation all bearing the name of the manufacturer.

1.7 TECHNICAL PROPOSAL

A. Technical proposals shall be prepared in accordance with these specifications. Copies of the proposal shall be submitted with the bid in bookmarked PDF format. The technical proposal shall include the following data/information as a minimum. The order of listing here is not intended to indicate, nor should it be construed to indicate, the relative importance of the data/information:

1. Information on organizational capability to handle this project (management, personnel, manufacturing, single source responsibility, etc.).
2. Information on training program to demonstrate specification compliance.
3. System Configuration as Proposed:
    a. Describe system architecture including a schematic layout with location and type (model number) of all control panels.
    b. Describe system operation, functions, and control techniques.
    c. Modularity.
    d. Migration strategies to protect owner’s investment in BMS system.
4. Technical data to support the information on the hardware and software proposed for this solution including any integrated systems and/or solutions.
5. Detailed description of all operating, command, application. and energy management software provided for this project.
6. A signed certificate stating the Contractor "has read the performance and functional requirements, understands them and his technical proposal will comply with all parts of the specification."
7. Line-by-line specification concordance statement.

8. Other requirements for inclusion in the technical proposal are located throughout this specification.

B. Submit technical proposals with pricing in accordance with Instructions to Bidders.

C. Failure to submit technical proposal containing the information outlined above will result in rejection of bidder's proposal.

1.8 SYSTEM PERFORMANCE

A. Comply with the following performance requirements:

1. Graphic Display: Display graphical information at the present day fastest refresh interval capable by the most current updated graphical software revisions within the confines of the firmware of the connected equipment.

2. Graphic Refresh: Display information at the fastest refresh interval of the most recent graphical software revision within parameters of the workstation.

3. Object Command: Reaction time shall be at the fastest refresh interval with the most current up-to-date graphical software version within the firmware capabilities of the connected equipment. In no case shall that be more than two seconds between operator command of a binary object and device reaction.

4. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.

5. Reporting Accuracy and Stability of Control: Report values and maintain measured variables to within industry standards and tolerances no greater than those as follows:

a. Space Temperature: ± 1°F
b. Ducted Air Temperature: ± 1°F
c. Outside Air Temperature: ± 2°F
d. Dew Point Temperature: ± 3°F
e. Temperature Differential: ± 0.25°F
f. Relative Humidity (indoor air): ± 3%rH
g. Relative Humidity (outdoor air): ± 2%rH
h. Airflow (pressurized spaces): ± 3% of full scale
i. Airflow (terminal): ± 10% of full scale
j. Air Pressure (space): ± 0.01-inch w.g.
k. Air Pressure (ducts): ± 0.1-inch w.g.
l. Carbon Monoxide: ± 5% of reading
m. Carbon Dioxide: ± 50 ppm
n. Chilled Water Temperature: ± 1°F
o. Heating Hot Water Temperature: ± 1°F
p. Water Pressure: ± 2% of full scale
q. Water Differential Pressure: ± 2 psig
r. Water Flow: ± 5% of full scale
s. Electrical: ± 5% of reading

1.9 SUBMITTALS

A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, options provided, finishes for materials, and installation and startup instructions for each type of product indicated.

1. DDC System Hardware: Bill of materials of equipment indicating quantity, manufacturer,

and model number. Include technical data for operator workstation equipment, interface equipment, control units, transducers/transmitters, sensors, actuators, valves, relays/switches, control panels, and operator interface equipment.

2. Control System Software: Include technical data for operating system software, operator interface, color graphics, programming, sequence of operations, and other third-party applications.
3. 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.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and specific location and size of each assembly and field connection.

1. See paragraph 2.3.A.2 for digital storage of controls shop drawings as-builts and product data sheets.
2. Bill of materials of equipment indicating quantity, manufacturer, and model number.
3. Catalog cut sheets for each component with highlighted selections and options.
4. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
5. Wiring diagrams for DDC system hardware with enumerated termination numbers.
6. Schematic diagrams for point-to-point control, communication, and power wiring. Show trunk data conductors and wiring between operator workstation and control unit locations.
7. Schematic diagrams and floor plans for field sensors and control hardware.
8. Details of control panel faces, including controls, instruments, and labeling.
9. Flow diagram and written description of sequence of operation for each system and component.
10. Detailed descriptions of DDC algorithms.
11. Schedule of dampers including size, leakage, and flow characteristics.
12. Schedule of valves including flow characteristics.
13. Control System Software: List of color graphics indicating monitored systems, data (connected and calculated) point addresses, output schedule, PDF links, and operator notations.
14. Controlled Systems:
    a. Schematic diagrams of each controlled system with control points labeled and control elements graphically and geographically shown, with wiring.
    b. Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.
    c. Written description of sequence of operation including schematic diagrams in PDF to be embedded on graphical screens.
    d. Points list with corresponding controller ID’s.
15. Submittal of graphical interface and graphical representations of each component.

C. Operation and Maintenance (O&M) Data: For HVAC instrumentation and control system, include as-built operation and maintenance manuals. The manuals are to be delivered in three media formats: hardcopy, USB thumb drive, and PDF with navigational links. Submission to include the following:

1. Maintenance instructions for each type of control device.
2. List of hardware and software spare parts.
3. Interconnection wiring diagrams with identified and numbered system components and devices.
4. Keyboard illustrations and step-by-step procedures indexed for each operator function.
5. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
6. Calibration records and list of set points.
7. Normal, range and failsafe position for each device.
8. Sequences of operation.

D. Provide submittals for fast-track items that need to be approved and released to meet the schedule of the project. Provide submittals for the following items separately upon request:

1. Valve schedule and product data
2. Damper schedule and product data
3. Mounting and wiring diagrams for factory-installed control components
4. Thermostat locations

E. Submit blank field check-out and commissioning test reports, customized for each panel or system, which will be filled out by the technician during start-up.

F. Variance letter: Submit a letter detailing each item in the submission that varies from the contract specification or sequence of operation in any way.

1.10 QUALITY ASSURANCE

A. Installer Qualifications: Automatic control system manufacturer's authorized representative who is trained and approved for installation of system components required for this Project, and who employs only factory trained personnel, with minimum experience as follows:

1. Firm: 10 years
2. Project Manager: 5 years
3. Project Engineer, Application Engineering Staff: 3 years
4. Electronic Technicians: 2 years

B. Approved manufacturers shall have minimum three full-time factory trained and certified service personnel located within twenty-five miles travel distance of CMS Building Services.

C. Comply with ANSI/ASHRAE Standard 135-1995 for DDC system components for BACnet/MSTP at the unit controller level.

D. Controls equipment and components shall meet or exceed the following standards: UL-916; Energy Management Systems (EMS).

E. Preinstallation Conference: Including Architect, Owner's representative, and affected Installers, to review approved submittals and installation strategies.

1.11 QUALIFICATION REQUIREMENTS

A. The EMS/BAS controls contractor must have a minimum of 10 years of experience manufacturing and installing the controls system similar in performance to that specified herein and shall be prepared to evidence this history as condition of acceptance and approval prior to bidding.

1.12 DELIVERY, STORAGE, AND HANDLING

A. Delivery of material shall not be considered complete until installed. Components shall be protected from detrimental environmental conditions until mounted at the component’s final location.

B. Storage shall be at the contractor’s risk and responsibility in collaboration with the Owner.

C. All material handling shall remain the contractor’s responsibility.

D. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.

1.13 COORDINATION

A. Coordinate location of thermostats, humidistats, and other exposed control sensors with owner, plans and room details before installation. All field installed components shall remain accessible for maintenance and repair.

B. Provide LED RIB Relays or approved devices for demarcation between 3rd party systems. Label all devices with function.

C. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.

D. Global site controllers shall have dedicated power circuits, with UPS and emergency generator backup.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers approved as listed below, each having critically defined data made available and integrated via BACnet/IP to CMS's most current version of Tridium's Niagara N4 frontend WebSupervisor having capabilities to hyperlink and navigate to any one of the following:

1. Automated Logic WebCTRL as provided by ALC in Charlotte, NC
2. Trane Tracer Ensemble as provided by Carolina Trane in Charlotte, NC
3. Johnson Controls Metasys as provided by Johnson Controls (JCI) in Charlotte, NC
4. Niagara N4 with Schneider Electric IA as provided by Schneider Electric, Charlotte, NC
5. Niagara N4 with (TBD) as provided by Platinum Building Automation
6. Niagara N4 with Honeywell as provided by United Automation Controls, Charlotte, NC

B. Comply with qualification requirement in above sections.

C. Pre-approval does not relieve the manufacturer from compliance of 230900.

2.2 CONTROL SYSTEM

A. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, and accessories to control mechanical systems. System must be hardwired controllers, and field devices, wireless, or IP-addressable when approved.

B. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to distributed controllers operating in multiuser, multitasking environment on BACnet network and programmed to control mechanical systems. An operator workstation permits interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics.

2.3 GENERAL

A. The BAS shall include, but not be limited to, the following components:

1. The BAS Operator Interface shall be accessible from any internet browser using HTML5 current technology via Windows 10 or greater OS from Microsoft Edge, Google Chrome, and/or Mozilla Firefox, and/or a mobile app. The Global Operator Interface is a graphical display providing efficient and effective navigation across multiple platforms initially through a higher-level CMS designated single web supervisor frontend with navigation capabilities to and through any one of the CMS five vendor specific secondary level frontends. The BAS Operator Interface consists of hardware and software that allows full user monitoring, adjustment of system parameters, fault detection and diagnostic capabilities. The systems shall support an unlimited number of password-protected concurrent users, if view only, and shall be individually identifiable if provided with command and control.
2. Digital storage of as-built control drawings and product data sheets including sequences of operation, and relevant project manual as-built drawings/information shall be in PDF format, stored on the virtual server, and made accessible from the site front page via a navigation link. BAS drawings and product data sheet PDFs are to be stored in the BAS by the building automation controls contractor. Drawings and other project information electronic PDFs are to

be provided by others and stored and made accessible in the BAS by the Controls Contractor.

3. System Level Controllers shall manage the Energy and Building Management capabilities of the automation system as well as facilitate remote communications and central monitoring.
4. Application Specific Controllers shall provide distributed, pre-engineered control, specific to the mechanical equipment specified.
5. Custom Application Controllers with distributed custom programming capability shall provide control for nonstandard control sequences.
6. The Data Communications capability shall allow data to be shared between the various controllers in the architecture.
7. The system software shall include system software for global application functions, application software for distributed controllers, and operator interface software.
8. End devices such as sensors, actuators, dampers, valves, and relays. All AI/AO and DI/DO must be compatible and afforded isolation/protection from 3rd party devices.
9. All 3rd party controllers read, write, and AV/BV values shall be BACnet compatible. All non-vendor specific controllers shall be preapproved by CMS.

B. The failure of any single component shall not interrupt the control strategies of other operational devices. System expansion shall be through the addition of end devices, controllers, and other devices described in this specification.

C. Hard-wired Safety circuit end of line devices shall reside in the same controller as the equipment being protected.

D. All Controllers shall automatically reboot and retain system properties programming and settings in the event of a power failure.

E. Provide a UPS for the BAS Server.

1. Basis of Design: APC, Liebert, or pre-approved equal.
2. The UPS shall power the device for a minimum of 30 minutes, in the case of power interruption.
3. The UPS shall be DIN rail mounted within the associated control panel and consist of a battery power source, charger, AC output inverter system and automatic load transfer circuits for a fully automatic operation. The UPS shall be an on-line type. When normal AC power returns, the UPS shall transfer the load to the rectifier output. At this time, the charger shall turn on to its 'high' charge rate until the batteries are charged approximately 80% of their rated capacity and then automatically shall switch to its maintenance 'sensing' position to keep the batteries in their best full-charge condition. Battery recharge time shall not be more than 3 hours.
4. Each UPS shall be provided, as a minimum, with pilot lights for the following conditions: "Incoming AC Power is Available", "UPS Ready Mode" and "UPS in Standby Mode.” The UPS shall have the capability to hot-swap batteries without interrupting the supply of power to its users.
5. The batteries shall be of the totally enclosed nickel-cadmium type or equal. Batteries that can leak gas shall not be acceptable. There shall not be any damages should the emergency outage of line power exceed the maximum operation time of the UPS. Automatic shutdown shall occur when the UPS' maximum duty cycle is exceeded.

2.4 DDC EQUIPMENT

A. Only CMS authorized and configured computers by Building Services Support Services Technology Group are permitted. All required software for the BAS Controls and DDC system diagnostics shall be loaded onto multiple CMS computers, compatible with current CMS technology. All necessary operational and utility software to operate, configure, maintain, program, trend, perform diagnostics, override control points, and edit graphics shall be provided and reside on the server. No annual renewal fees shall be required on software.

B. Building Controls Contractor shall coordinate with Owner’s IT department to interface with the local

demilitarized zone (DMZ) network. The DMZ subnetwork is logistically located between the public internet and private networks. The contractor shall be responsible to coordinate the security of the BAS network.

2.5 BUILDING AUTOMATION FUNCTIONS

A. System Graphics: The BAS panel shall serve up HTML5 type data and standard equipment graphics pages. No special software on any remote computer shall be required to view/edit the graphics. IT connectivity shall be provided by Owner. The BAS GUI shall also have a navigation tree. Provide a standardized and consistent method in conjunction with existing navigation for the operator to easily move between graphic displays. See section 230901 for information on Graphical User Interface and Tree and Branch Layouts. The building initial site summary page shall contain the following data:

1. Top banner with school name, outside air temperature, humidity, and enthalpy.
2. Graphical link to control drawings, sequence of operation, and equipment schedules.
3. Global cooling and heating setpoints of 74°F (adj.) and 70°F (adj.) for Occupied and Unoccupied space temperatures. All setpoints shall be user-adjustable via the BAS frontend.
4. Floor plan with the following functionality:
    a. Hyperlinks to the represented areas.
    b. Approved naming description of the areas (e.g., Admin, Café, Classroom Wing “x”, etc.). Room numbers must match architectural building room numbers.
    c. Individual floor plans with links for mechanical equipment and any space sensors positioned geographically on the plan.
    d. Flood fill for any alarm in the area.
    e. Needle-point bi-polar ionization alarming.
5. Quick links to all AHU’s, Chiller plant, and Boiler plant.
6. AHU Summary listing Occupancy status, Supply Fan status, Discharge Air temperatures, and Alarms.
7. Chiller Plant Summary with chiller status, pump status, supply and return temperatures, system flow and system differential pressure.
8. Boiler Plant Summary with boiler status, pump status, supply and return temperatures, system flow and system differential pressure.
9. Quick link to schedules
10. Summer/Winter Mode selection
11. Energy Data (gas and electricity), where applicable
12. Links to any miscellaneous systems not listed above, but specifically requested by CMS.

B. Data on web pages must be returned and updated on a given web page at the maximum interval the control processor can deliver, but no less than 5 seconds.

C. System Applications. Provide the following applications:

1. Area Control: Area application coordinates HVAC equipment for a specific area of the building. The application shall assign unit controllers, binary outputs, and binary values to be members of a common area to efficiently perform a single operation (such as changing a setpoint, creating a schedule, performing an override) and apply it to all members of the area. In addition, the area application shall use algorithms, along with area temperatures and humidity inputs, to make an economizing decision. The application shall also include optimal start/stop, humidity pulldown, night purge, unoccupied heating/cooling, unoccupied humidify, unoccupied dehumidify, and timed override functions.
2. Integration: Energy-saving applications, including static pressure optimization and ventilation optimization, are required features. Control sequences of dedicated primary pumps shall be provided by the dedicated primary system served, (e.g., Boilers, Chillers, etc.) BAS DDC functionality can be supplemented with BACnet connections for feedback, provided stand-alone and local capabilities and safety sequences are not compromised. Safety circuits should not be wired through the BAS.

3. Reports features: The operator interface shall provide a reporting package that allows the operator to select reports. Standard reports for equipment shall be made available from the BAS. These reports provide a valuable source of data that can be used for record-keeping and troubleshooting. The operator interface shall provide a reporting package that allows the operator to select reports, and schedule reports to run at specified time intervals. The operator interface shall allow a user to export reports and logs from the building controller in a format that is readily accessible by other standard software applications, including spreadsheets and word processors. Report types shall include:
   a. Site reports
   b. All Points in Alarm Report: Provide an on-demand report showing all current alarms
   c. All Points in Override Report: Provide an on-demand report showing all overrides in effect
   d. Points report: Provide a report that lists the current value of all points
4. System Diagnostics: The BAS shall automatically monitor and report the operation and condition of all network connections, building management panels, and controllers. High level notification of critical alarms will be reported and displayed at the Global N4 Tridium Single-Entry initial navigation page from all CMS EMS/BAS control platforms. On the Global page, all CMS sites will be listed in alphabetical order and have the following summarized notification of 3 critical alarms:
   a. Network Comm/Site's BAS Controller Down,
   b. Site Mechanical Plant Chiller, Boiler, Ancillary Equipment Down
   c. NPBI Module Non-Functional
6. Override Point Control: Provide a tracked method for a user to view, override, and edit if applicable, the status of any object and property in the system. The point status shall be available by menu, on graphics, or through custom programs. A summary log of all Overrides, the point(s) overridden, by whom, when, and for how long shall be on the BAS front end. All overrides shall have a default "TEMPORARY TIMED-OPTION" with an automatic return to the designed setting parameter. Permanent operator overrides shall only be assigned with high level password access.
7. Override Owners: The system shall convey to the user the owner of each override for all priorities that an override exists. Provide a specific icon to show timed override or operator override, when a point, unit controller or application has been overridden manually.
8. Data Logs: Provide data logs for each major piece of equipment (chillers, boilers, air handling units, rooftop units, and pumps). Temperature sensors in IDF/MDF rooms shall also be trended. Logs shall be capable of being viewed in real-time, or later (historical data) in graphical and tabular format. They shall also be capable of being printed and saved. With the proper security access, system users can configure (create, delete, and update) and manage (clear, enable, and disable) data logs in the system. Each point in the data log should clearly be delineated by color and key in a multiple simultaneous per data log capability. The operator interface shall allow a user to export trend log data in CSV or PDF format for use by word processing and spreadsheet packages such as Microsoft Office Word and Excel. Data logs shall be able to be stored for up to three years.
10. Scheduling: Schedules by ventilation space (e.g., AHU, RTU, FCU, etc.) or areas (e.g., Admin, Media Center, Kitchen, Cafeteria, Gym, Classroom Wing "x", etc.) shall be programmed into the system at owner turnover and confirmed during owner training. A user shall be able to perform the following tasks utilizing the operator interface:
    a. Edit an existing schedule.
    b. Create a new schedule.
    c. Define the default values, events, and membership.
    d. Create exceptions to a schedule for any given day, and/or hours within a day.
    e. Create Schedule Groups comprised of an arbitrary group or areas, rooms, or equipment scattered throughout the site.
    f. Apply an exception that spans a single day or multiple days, independent or consecutive (e.g., Holiday, Events, etc.)
    g. View a schedule by day, week and month with exceptions, schedules, and holidays

characterized and shown clearly in a calendar format

h. Modify the schedule events, members, and exceptions.

Scheduling should be able to be deployed and integrated by facility-type (ES, MS, HS, Admin, et al) from the BAS and the N4 Tridium High level frontend GUI. Overlapping schedules shall be clearly indicated and displayed.

11. Alarm/Event Notification: An operator shall be notified of new alarms/events as they occur while navigating through any part of the system via an alarm icon. A display of the last Alarm and counter of the same previous alarms in history is preferred.
12. Alarm/Event Log: The operator shall be able to view all logged system alarms/events from any operator interface. The operator shall be able to sort and filter alarms from events. Alarms shall be sorted in a minimum of 4 categories based on severity. Alarm/event messages shall use full language, easily recognized and consistent descriptors. An operator with the proper security level may acknowledge and clear alarms/events. All alarms/events that have not been cleared by the operator shall be stored by the building controller. The alarm/event log shall include a comment field for each alarm/event that allows a user to add specific comments associated with any alarm.
13. Alarm Processing: Any object in the system shall be configurable to alarm in and out of normal state. The operator shall be able to configure the alarm limits, warning limits, states, and reactions for each object in the system. If an alarm exists, an alarm shall be uniquely visible in the GUI and Global navigation bars (N4 & Vendor Platforms). The data displayed in the log includes when and where the event occurred and whether the operator is required to acknowledge it. An operator shall also have the capability to use the log to add comments about events. Column headings can be used to sort and filter events. They shall also be available to be removed or exported from the log.
14. Alarms and Events: Log shall contain multiple categories that can be used to sort and filter them. Sorting shall be based, for example, on severity level. Filtering shall be used to view only the alarms from a specific piece of equipment, or space, or those received at a specific time or from a specific alarm category.
15. Security: Each operator shall be required to login to the system with a unique username and password to view, edit, add, or delete data. Multiple User Profiles shall be provided to restrict the user to only the objects, applications, and system functions as assigned by the system administrator. User logon/logoff attempts shall be recorded. The system shall protect itself from unauthorized use by automatically logging off after a predetermined adjustable time following the last keystroke. The delay time shall be administrator definable by log in.
16. Pre-defined Profiles: The system shall include pre-defined profiles that allow a system administrator to quickly assign levels of permissions to a user or group of users.
17. Help: Provide a context sensitive, online help system to assist the operator in navigation and configuration of the system. On-line help step by step shall be available for all system functions and shall provide the relevant data for each screen.
18. Network Monitoring: The system shall automatically monitor the operation of all network connections, building management panels, and controllers. The failure of any device shall be annunciated to the operators and geographically depict the fault location.
19. Controls contractor shall provide commissioning agent all controls software at no additional cost.

2.6 ARCHITECTURE/COMMUNICATIONS

A. This project shall be comprised of a high-speed Ethernet network utilizing BACnet/IP communications between System Server, Controllers, and Workstations. Communications between System Controllers and sub-networks of Custom Application Controllers and/or Application Specific Controllers shall utilize BACnet/IP (owner preferred) or wireless communications.

1. Each System Controller shall perform communications to a network of Custom Application and Application Specific Controllers using BACnet protocol as prescribed by the BACnet standard. Each System Controller shall function as a BACnet Router to each unit controller providing a unique BACnet Device ID for all controllers within the system.

2.7 SYSTEM LEVEL CONTROLLERS

A. System level controller shall reside on the CMS enterprise-Wide Area Network (WAN). The enterprise WAN is provided by the owner and supports the Internet Protocol (IP). Local Area Network (LAN) connections for the Building Controllers shall be provided by the controls contractor on ISO 8802-3 (Ethernet). Each Building Controller shall also perform routing to a network of Custom Application and Application Specific Controllers. Each Building Controller shall perform communications to a network of Custom Application and Application Specific Controllers using BACnet/MSTP. Each System Controller shall be listed as a Building Controller (B-BC) by the BACnet Testing Lab.

B. System level controller shall support hardwire communications to equipment level direct digital controllers. Multiplexing of receivers and transmitters is not acceptable.

C. Each System Level Controller shall function as a BACnet Router to each unit controller providing a unique BACnet Device ID for all BACnet/MSTP controllers within the system.

D. The System Level Controller shall have ample memory to support its operating system, database, and programming requirements. All trending history shall be stored at the system level controller for 48 hours and then automatically downloaded to the CMS server.

E. The System Level Controller shall store database and programming files.

F. The operating system of the System Level Controller shall manage the input and output communications signals to allow distributed controllers to share real and virtual point information and allow central monitoring and alarms.

G. Data shall automatically be shared between System Level Controllers when they are networked together. All System Controllers shall have a real-time clock.

H. The database and custom programming routines of remote System Level Controllers shall be editable from a single operator station.

I. The System Level Controllers shall have the capability of being remotely monitored over LAN. Additional capabilities shall include automatically sending out alarms, gathering alarms, reports and logs, programming and downloading databases.

J. The controller shall continually check the status of all processor and memory circuits. If a failure is detected, the controller shall:

1. Assume a predetermined fail-safe failure mode.
2. Emit an alarm condition, displaying visually on graphics and/or audibly, and/or via email or SMS.
3. Create a retrievable file of the state of all applicable memory locations at the time of the failure, unless latched.
4. Automatically reset the System Controller to return to a normal operating mode.
5. Automatically reboot with all programming and memory function intact upon a voluntary or involuntary power cycle.

K. Controller hardware shall be suitable for the anticipated ambient conditions. Controller used in conditioned ambient shall be mounted in an enclosure and shall be rated for operation at -40°F to 122°F.

2.8 EMS/BAS APPLICATION SPECIFIC CONTROLLERS

A. Application Specific Controllers (ASC) shall be stand-alone, microprocessor based DDC controllers with sufficient memory to handle its operating system, database, and programming requirements of the BAS. These controllers are assumed to be used for AHUs, Chillers, Boilers, etc.

B. The ASC shall be pre-programmed, tested, and factory mounted on the mechanical equipment to ensure reliability. Where factory mounting is not possible, the controllers shall be factory programmed and tested prior to shipment to the jobsite. The controllers shall be clearly labeled as to controller type, where it is to be installed, and software address (if applicable). The controller shall be fully tested upon installation to ensure that it is properly matched to the equipment it is controlling.

C. The controller shall communicate with other devices on the communication network and be fully integrated with the other system components.

D. The BACnet ASC shall provide I/O points based on the points list to fulfill the sequence of operation section of the Construction Documents. BACnet Unitary application- specific controllers shall provide I/O points based on the points list in the sequence of operation. The controller shall include, as required by the points list or sequence of operation, two of each additional AI/AO/BI/BO points beyond what is shown on the points list.

E. The hardware shall be suitable for the anticipated ambient conditions:

1. Controllers used outdoors, or in wet ambient areas, shall be mounted within waterproof enclosures, and shall be rated for operation at -40°F to 155°F.
2. Controllers used in conditioned ambient areas shall be mounted in dust-proof enclosures, and shall be rated for operation at 32°F to 120°F.

F. The ASC unit controller shall be dedicated for each ASC unit, with one single processor to handle all points specified.

2.9 EMS/BAS CUSTOM APPLICATION CONTROLLERS

A. The Custom Application Controllers (CAC) shall provide stand-alone control and require no additional system components for complete operation. It shall have sufficient memory to support its operating system, database, and programming requirements. The controller shall communicate with other devices on the communication network and be fully integrated with the other system components. All controllers shall be BACnet BTL listed communications MSTP.

B. The BACnet CAC shall have built-in I/O points based on the points list in the sequence of operation section of the Construction Documents. All programming required for operation shall be memory resident and shall be retained in permanent memory.

C. The CAC shall be configured such that the Portable Operator Interface can be plugged directly into it or within sight for programming, editing, and other operator functions.

D. Controller hardware shall be suitable for the anticipated ambient conditions:

1. Controllers used outdoors, or in wet ambient areas, shall be mounted within waterproof enclosures, and shall be rated for operation at -40°F to 155°F.
2. Controllers used in conditioned ambient areas shall be mounted in dust-proof enclosures, and shall be rated for operation at 32°F to 120°F.

2.10 CONTROLLERS SOFTWARE PROGRAMMING, CONFIGURATION, SERVICE TOOL

A. Provide one copy of software programming and service tool that is specifically compatible with the BACnet unit level controllers. This software shall be registered and shall be property of the Owner at project completion. This software tool shall not have installer license restriction that prevents the Owner or his servicing agent from use of the tool. The software tool shall not require annual subscription or renewal fees.

B. The software service tool shall be installed on Owner’s provided computer and transferrable to any other CMS computer.

C. The software service tool shall have the ability to perform the following tasks:

1. View Controller status.
2. View status of points and alarms.
3. Create, edit, and override points.
4. Configure and commission System, Application Specific, and Custom Programmable controllers.
5. View data logs.
6. Download configuration files, logic program files, and firmware.
7. Upload programs.
8. Backup and restore firmware, configuration files, and logic program files.
9. Create and edit graphics.
10. Modify existing control program.
11. Add new points and edit database.

2.11 INPUT/OUTPUT INTERFACE

A. Hardwired inputs and outputs may tie into the system through System Application, Custom Application, or Application Specific Controllers. Slave devices are also acceptable. Any critical points requiring immediate reaction shall be tied directly to the controller hosting the control algorithm for the critical function.

B. Binary inputs shall allow the monitoring of on/off signals from remote devices. The binary inputs shall be compatible with commonly available control devices. All status points shown on the point list shall be positive proof differential pressure or current sensing binary switches.

C. Analog inputs shall allow the monitoring of low voltage, current, or resistance signals and shall have a minimum resolution of 0.1 percent of the sensing range. Analog inputs shall be compatible with, and field configurable to, commonly available sensing devices.

D. Binary outputs shall provide a continuous low voltage signal for on/off control of remote devices.

E. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0-10 VDC or a 4-20 mA signal as required to provide proper control of the output device.

F. Universal and pulse inputs shall be supported.

G. System architecture shall allow for point expansion in one of the following ways:

1. The addition of input/output cards to an existing System Application Controller.
2. A slave controller may be used to expand point capacity.

2.12 AUXILIARY CONTROL DEVICES

A. Motorized dampers: Ruskin Model CD-60 or approved equal

1. All dampers shall be high velocity, low leakage dampers. Field replaceable edge and end seals shall be installed along the top, bottom, and side of the frame and each blade. Seals and bearings shall be suitable for temperature ranges from -40°F to 200°F. Leakage shall not exceed 6 CFM/ft^2 at 4 inches w.c. differential pressure. Damper frames and blades shall be galvanized steel and a minimum of 16 gauge. Blade width shall not exceed 8 inches.
2. All proportional dampers shall be opposed blade type. Two position dampers may be opposed or parallel blade type.

B. Electric Damper Actuators: Belimo

1. Damper actuators shall be electronic, spring return, low voltage (24VAC) and shall be properly sized to stroke the damper smoothly and efficiently throughout its range. Actuator response shall

be linear in response to sensed load. End of each damper rod shall be permanently-scored to indicate physical position of damper blades. Spring return actuators with more than 60 in-lb. torque capacity shall have a manual crank for this purpose.

2. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Unless noted in the sequence of operation or utilized for outside air, for VAV box, Unit Ventilators, Fan Coil Units or terminal units, floating actuator fail in place is permitted. VAV boxes may be as provided by controls manufacturer if Belimo actuator is integrated into the manufacturer's controller if parts are fully interchangeable.
3. Outside air dampers shall fail closed. Return air dampers shall fail open. Relief damper shall fail closed.
4. All Outside Air, Relief Air, and Return Air damper actuators associated with units that have static safety pressure switches shall have position proving switches or blade switches.
5. All dampers shall be equipped to allow manual override.

C. Control Valves: Belimo

1. See Specification 230923 – "Control Valves" for further details.
2. Control valves shall be two-position isolation or modulating service as scheduled or shown. Valves 1/2" through 3" shall be forged brass body, stainless steel ball and stem, PTFE seat, EPDM packing, equal percentage flow. Valves 4" and larger shall be cast iron body, bronze seats, stainless steel stem, bronze plug, no lip packing, ANSI class 125, leakage class III, flanged end fitting.
3. Body, trim style, and materials shall be per manufacturer's recommendations for design conditions and service shown.
4. Control valves shall not be smaller than one pipe size of the connected hydronic coil.
5. Isolation valves shall be line size full port, 2 position control.

D. Electric Control Valve Actuators: Belimo, fully integrated into actuator.

1. Chilled water valves shall fail to 50% open, except as allowed in paragraph D.7 below. Hot water valves shall fail open except as allowed in paragraph D.7 below.
2. Valve actuators shall be electronic, low voltage (24VAC), and properly selected for the valve body and service. Actuator shall have clutch or gear operator for manual operation.
3. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the valve when the actuator is not powered. Spring return actuators with more than 60 in-lb. torque capacity shall have a manual crank for this purpose.
4. The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator.
5. Modulating actuators for central plant 3-way mixing control valves shall be provided with a 2-10 VDC or 4-20 mA position feedback signal.
6. Actuators shall be provided with a conduit fitting and a minimum 3-foot electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.
7. Unless noted in the sequence of operation for Unit Ventilators, Fan Coil Units, or terminal units, floating actuator fail in place is permitted.

E. Temperature Sensors: Kele, or approved equal

1. Temperature sensors shall be Thermistor-type 10k ohm as dictated by the requirements of this specification. Thermistors are acceptable for space temperature sensors and other monitoring-only points.
2. Space sensors shall be a type 2 wall plate type sensor, in a vandal-proof enclosure. Where applicable they should also include humidity, and CO2. Accuracies shall be ± 1°F. No setpoint adjustment by occupants shall be provided unless specifically indicated on the drawings. Where setpoint adjustment is required, range of adjustment shall be limited to ± 2°F from setpoint defined

by control sequences.

3. AHU unit sensors shall be averaging as specified in the sequence of operations. Averaging sensors shall be a minimum of 6 feet in length. For existing application, or where installed in ductwork exterior to the AHU, a 12" duct probe is acceptable.
4. Hydronic pipe immersion sensors shall be provided with a separable stainless steel well. Immersion sensor probe length shall be sized to meet pipe diameter requirements. Manufacturer's thermal lubricant shall be provided. All external trim material shall be corrosion resistant designed for the intended application.

F. Flow and Status Switches: Kele, JCI, Trane, Veris

1. Current sensing relays may be used for flow sensing or terminal devices, as shown. Current-operated switches shall be self-powered, solid state with adjustable trip current. The current switches shall be selected to match the current and electrical characteristics of the equipment being monitored and the application and output requirements of the DDC system.
2. Paddle type switches (water service only) shall be UL listed, SPDT snap-acting with pilot duty rating (125 VA minimum). Adjustable sensitivity with NEMA 1 Type enclosure unless otherwise specified.
3. Differential pressure type switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum), NEMA 1 Type enclosure with scale range, adjustable high/low settings, and differential suitable for intended application, or as specified. Switches shall reset automatically when conditions return to normal, unless otherwise indicated.
4. Water Differential Pressure Switches and shall be installed with full port isolation valves and gauge test ports and made fully accessible or piped to an area where access is afforded without the use of scaffolding or a lift.

G. High Limit Thermostats: Kele, or approved equal

1. High limit thermostats shall be manual reset type set at 120°F.

H. Low Limit Thermostats and Line Voltage Thermostat: Kele, or approved equal.

1. Safety low limit thermostats shall be vapor pressure type with $1ft^2$ coil area per foot of capillary. Element shall respond to the lowest temperature sensed by any one-foot section.
2. Low limit shall be DPDT manual reset only rated for the application.
3. Where required multiple low limit thermostats shall be installed.
4. Low-Voltage Space Thermostats shall be 24VAC, bimetal-operated, mercury-switch type, with either adjustable or fixed anticipation heater, concealed setpoint adjustment, 55 to 85°F setpoint range, 2°F maximum differential, and vented cover.
5. Line-Voltage Space Thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 55 to 85°F setpoint range, 2°F maximum differential, and vented cover.

I. Carbon Dioxide (CO^2) Sensors: E+E Elektronik, or approved equal

1. Carbon Dioxide sensors shall measure CO^2 in the range of 0-2000 ppm. Accuracy shall be ± 3% of reading with stability within 5% over 3 years. Sensors shall be outside, duct, or space mounted as indicated in the sequence of operation.

J. Interface High Voltage/Current Control Relays: RIB or approved equal

1. Control relays shall be UL listed. Contact rating, configuration, and coil voltage suitable for application.
2. Control relays shall be provided with LEDs to indicate status of the coil.
3. Current sensing relays shall be split core.
4. Time delay relays shall be UL listed dry contact input. Delay shall be adjustable ± 200%

(minimum) from set-point shown on plans. Contact rating, configuration, and coil voltage suitable for application. Provide NEMA 1 Type enclosure when not installed in local control panel.

K. Air and Water Static/Differential Pressure Sensors: Kele, Veris or approved equal

1. Sensor shall have linear output signal. Zero and span shall be field-adjustable.
2. Sensing elements shall withstand continuous operating conditions ± 50% greater than calibrated span without damage.
3. Air static or differential pressure sensors shall have range appropriate for their application.
4. Water pressure sensor shall have stainless steel diaphragm construction; minimum operating pressure of 150 psig. Sensor shall be complete with 4-20 mA output, required mounting brackets, and block and bleed valves. Mount in location accessible for service.
5. Water differential pressure sensor shall have stainless steel diaphragm construction; minimum operating pressure of 150 psig. Over-range limit (DP) and maximum static pressure shall be 3,000 psig. Transmitter shall be complete with 4-20 mA output, required mounting brackets, and five-valve manifold. Mount in a location accessible for service.
6. Water differential pressure sensors and transducers shall be installed with full port isolation valves and gauge test ports and made fully accessible, either in a mechanical room or within 24" of an accessible ceiling.

L. Humidity Sensors: Kele, or approved equal

1. Space humidity sensors shall have a sensing range of 20 to 80%rH with an accuracy of ± 3%rH. Space sensors shall have blank covers with no humidity display and no setpoint adjustment.
2. Outdoor air humidity sensors installed outdoors or in HVAC outside air ductwork shall provide both relative humidity and dewpoint outputs. Sensors shall be impervious to damage by humidity levels exceeding 95%rH and wetting by rain or surface condensation. Measurement range shall be 20 to 95%rH with an accuracy of ± 2%rH. Sensors shall be suitable for ambient conditions of -40 to 170°F. Sensors installed outdoors shall include a weatherproof enclosure.
3. Duct humidity sensors shall be dedicated duct-mounted probe type providing both relative humidity and dewpoint outputs. Sensors shall be impervious to damage by humidity levels exceeding 95%rH and wetting by rain or surface condensation. Measurement range shall be 20 to 95%rH with an accuracy of ± 2%rH. Sensors shall be suitable for ambient conditions of -40 to 170°F.
4. Humidity sensor's drift shall not exceed 1% of full scale per year.

M. Water Flow Metering: Onicon, or approved equal

1. Basis of design: Onicon F-3500 Series insertion electromagnetic dual turbine flow meter.
2. Provide an insertion electromagnetic flowmeter complete with NIST traceable, wet calibrated flow-measuring element, integral transmitter, installation valves, installation depth gage and calibration certificate. Flowmeter shall be wet tappable, allowing insertion and removal from the flow stream without system shutdown.
3. Flowmeter shall be constructed, calibrated, and scaled for the intended application in terms of pipe size, pipe material, installation requirements, expected flow rate, ambient conditions and fluid characteristics which include but are not limited to pressure, temperature, conductivity, and viscosity.
4. All wetted metal components shall be 316 stainless steel.
5. Sensor shall be suitable for ambient conditions of -40 to 140°F, 5-100%rH (non-condensing); maximum pressure of 400 psig.; maximum temperature rating of 200°F.
6. Accuracy shall be ± 1% of rate from 2.0 to 20.0 ft/sec velocity (10:1 turndown ratio). Below 2.0 ft/sec accuracy shall be ± 0.02 ft/sec.
7. Transmitter shall provide (1) 4-20mA output signal proportional to water flow rate in gpm.

N. Air Flow Measuring Stations - Fan Inlet: Ebtron Gold Series, or approved equal

1. Basis of design: Ebtron GTx108e-F.
2. Provide a thermal airflow measuring station suitable for installation in the inlet cone of each centrifugal fan or inlet bell of tubeaxial and vaneaxial fans for each location indicated on the drawings, schedules, or control diagrams. Duct or plenum measurement shall not be substituted for fan inlet measurement devices or plenum measurement devices indicated on plans.
3. Each airflow monitoring station shall use the principle of thermal dispersion to determine actual or mass airflow rate of the airstream to continuously monitor the fan airflow rate and velocity. Differential pressure-based devices, including pitot tubes, pitot arrays, piezo-rings and devices measuring the pressure drop across a louver or damper shall not be acceptable.
4. Each sensor node shall have face, forward, or flare mount adjustable brackets and 304 stainless steel mounting feet for mounting in or on the fan inlet. Air flow monitoring station shall not obstruct the fan inlet nor have any effect on fan airflow performance or sound power levels.
5. Ensure sensor accuracy of ± 2% of reading over the entire operating range, over a temperature range of -20 to 160°F, and a humidity range between 0-100%rH (non-condensing).
6. Transmitters shall be provided with a 16-character by two-line, backlit, alpha-numeric LCD to display the airflow rate. Transmitters shall provide (1) linear analog output signal for airflow.

O. Air Flow Measuring Stations – Duct Probe: Ebtron Gold Series, or approved equal

1. Basis of design: Ebtron GTx116E-PC.
2. Provide a thermal airflow measuring station suitable for installation in ducts and plenums for each location indicated on the drawings, schedules, or control diagrams. Fan inlet measurement devices shall not be substituted for duct or plenum measurement devices indicated on plans.
3. Each airflow monitoring station shall use the principle of thermal dispersion to determine actual or mass airflow rate of the airstream to continuously monitor the fan airflow rate and velocity. Differential pressure-based devices, including pitot tubes, pitot arrays, piezo-rings and devices measuring the pressure drop across a louver or damper shall not be acceptable.
4. Probes shall have integral 304 stainless steel mounting brackets for insertion, internal, or standoff mounting. The probe(s) shall not have any effect on airflow or sound power levels in the duct or plenum.
5. Ensure sensor accuracy of ± 3% of reading over the entire operating range, over a temperature range of -20 to 160°F, and a humidity range between 0-100%rH (non-condensing).
6. Transmitters shall be provided with a 16-character by two-line, backlit, alpha-numeric LCD to display the airflow rate. Transmitters shall provide (1) linear analog output signal for airflow.

P. Transformers and Power Supplies

1. Control transformers shall be UL listed, Class 2 current-limiting type, or shall be furnished with resettable over-current protection in both primary and secondary circuits for Class 2 service.
2. Unit output shall match the required output current and voltage requirements. Current output shall allow for a 50% safety factor. Output ripple shall be 3.0 mV maximum Peak-to-Peak. Regulation shall be 0.10% line and load combined, with 50 microsecond response time for 50% load changes. Unit shall have built-in over-voltage protection. Unit shall be UL recognized.
3. Controller Power supplies shall be conditioned and not loaded more than 75% of rated capacity.

Q. Integrated Boiler Controls

1. Shall be BACnet compatible and interfaced to the BAS with sufficient capabilities to satisfy the control sequences of the equipment served.
2. Binary Values (BV) shall be provided for monitoring system status and fault indication.
3. Integration of systems to BAS for Class II circuits over 50 volts shall be provided by LED RIB Relays. Each RIB Relay shall be clearly identified.
4. All internal and external safety circuits for Boiler protection shall be internal to Boiler controls. All safety circuit wiring shall be direct from safety devices to equipment controller.

R. Integrated Chiller Controls

1. Shall be BACnet compatible and interfaced to the BAS with sufficient capabilities to satisfy the control sequences of the equipment served.
2. Binary Values (BV) shall be provided for monitoring system status and fault indication.
3. Integration of systems to BAS for Class II circuits over 50 volts shall be provided by LED RIB Relays. Each RIB Relay shall be clearly identified.
4. All internal and external safety circuits for Chiller protection shall be internal to Chiller controls. All safety circuit wiring shall be direct from safety devices to equipment controller.

S. Integrated VFD Controls

1. Shall be BACnet compatible and interfaced to the BAS with sufficient capabilities to satisfy the control sequences of the equipment served.
2. Binary Values (BV) shall be provided for monitoring system status and fault indication.
3. Integration of systems to BAS for Class II circuits over 50 volts shall be provided by LED RIB Relays. Each Rib Relay shall be clearly identified.
4. All internal and external safety circuits for connected equipment protection shall be internal to VFD controls.
6. For multiple motors powered from a single VFD, Manual Motor Starters and current transducers shall be provided for each motor in an array and integrated into the VFD.

T. Power and Energy Metering: Veris, or approved equal

1. Basis of Design: Veris E50H2 Advanced Power Meter
2. Power meter shall be fully electronic with multi-line backlit LCD display showing measured parameters as well as alarm functions and pulse output.
3. Power meter shall accept input from three (3) current transducers and perform the following measurements:
   a) Accumulated Real Energy (kWh) for each phase and total of all phases
   b) Accumulated Reactive Energy (kVARh) and Apparent Energy (kVAh) totals for all phases
   c) Net Present Demand for Real (kW), Reactive (kVAR) and Apparent (kVA) Power over a user-specified interval (block or sliding window)
   d) Maximum (Peak) Real (kW), Reactive (kVAR) and Apparent (kVA) Demand Intervals
   e) Instantaneous Real (kW), Reactive (kVAR) and Apparent Power (kVA), by phase and in total
   f) Current (amps) for each phase and average of all phases
   g) Phase-to-phase voltage for each phase and average of all phase pairs
   h) Phase-to-neutral voltage for each phase pair and average of all phases
   i) Power factor for each phase and average of all phases
   j) AC frequency
4. Power meter shall communicate using the BACnet protocol. The meter shall provide a BACnet Device object, a set of writable Analog_Value objects for remote configuration, a set of Analog_Input objects to provide access to scaled 32-bit measurement values and their unit types, and a set of Binary_Input objects for indicating individual alarm conditions.
5. The meter shall operate from -22°F to 158F and be available with an optional NEMA 4X enclosure.

2.13 ENERGY MANAGEMENT SYSTEMS (EMS) SOFTWARE

A. The following Energy Management capabilities shall be furnished standard as part of the BAS Panel.

B. Trend Log Application

1. Trend log data shall be sampled and stored on the System Controller panel and shall be capable of being archived to a BACnet Workstation for longer term storage.
2. Trend logs shall include interval, start-time, and stop-time.

3. Trend log intervals shall be configurable as frequently as 1 minute and as infrequently as 1 year.
4. The system controller shall automatically create trend logs for defined key measurements for each controlled HVAC device and HVAC application.
5. The automatic trend logs shall monitor these parameters for a minimum of 7 days at 15-minute intervals. The automatic trend logs shall be user adjustable.
6. Trend log shall be maintained for three years.

C. Optimum Start/Stop

1. An optimum start/stop program shall determine the required equipment start/stop timing by applying inside/outside temperature information to the user's time of day schedule.
2. The optimum start/stop program shall run independently for each controlled load or zone.
3. The program shall automatically adjust itself based on historical data, limited to 4 hours.

D. Alarm/Event Log

1. Any object in the system shall be configurable to generate an alarm when transitioning in and out of a normal or fault state.
2. Any object in the system shall allow the alarm limits, warning limits, states, and reactions to be configured for each object in the system.
3. An alarm/event shall be capable of triggering any of the following actions: Route the alarm/event to one or more alarm log, route an e-mail message to an operator(s), Log a data point(s) for a period, Run a custom control program.

E. Chilled Water System. Graphical representation of the Chiller Plant, including all chillers, pumps, piping, valves, and any ancillary equipment on a comprehensive one-line diagram. All setpoints to be user-adjustable from this screen. An operator shall be able to view and control (where applicable) the following parameters via the operator interface:

1. Mode of the chiller plant.
2. Current stage of the chiller plant.
3. Chiller enable/disable status.
4. Chiller or support system alarms.
5. Chilled water supply setpoint.
6. Primary supply and return water temperature for each chiller.
7. Secondary supply and return water temperature.
8. Secondary differential pressure and flow.
9. Primary and Secondary pump status.
10. Three-way mixing valve position.
11. Operator description as to when an additional chiller will be added or removed from operational sequence.
12. Chiller BACnet controller points and parameters, if applicable.
13. Capability to override all chillers, pumps, and valves.
14. Control to remove a chiller from a sequence temporarily for service purposes.
15. In addition to system flow graphics, provide a system operator information screen.

F. Boiler System. Graphical representation of the Boiler Plant, including all boilers, pumps, piping, valves, and any ancillary equipment on a comprehensive one-line diagram. All setpoints to be user-adjustable from this screen. An operator shall be able to view and control (where applicable) the following parameters via the operator interface:

1. Mode of the boiler plant.
2. Boiler enable/disable status.
3. Boiler or support system alarms.
4. Heating hot water supply setpoint.
5. Primary supply and return water temperature.

6. Secondary supply and return water temperature.
7. Secondary outside air reset set point and override.
8. Secondary differential pressure and flow.
9. Primary and Secondary pump status.
   Three-way mixing valve position.
10. Operator description as to when an additional boiler will be added or removed from operational sequence.
11. Boiler BACnet controller points and parameters, if applicable.
12. Capability to override all boilers, pumps, and valves.
13. Control to remove a boiler from a sequence temporarily for service purposes.
14. In addition to system flow graphics, provide a system operator information screen.

G. RTU, AHU, FCU, UV Systems. Graphical representation of the RTU, AHU, FCU, or UV system. All setpoints to be user-adjustable from this screen. An operator shall be able to view and control (where applicable) the following parameters via the operator interface:

1. Occupancy status.
2. Fan command, status, and speed.
3. Static pressure.
4. Outside air flow data.
5. Supply air temperature.
6. Return air temperature, humidity, and CO2.
7. Mixed air temperature.
8 Space temperature, humidity, and CO2.
9. Needle-point bi-polar ionization status and alarm.
10. Control valve percentage.
11. Damper percentage.
12. Electric duct heater stage and status.
13. Economizer status.
14. Freeze-stat status.
15. Capability to override all fans, valves, and dampers.
16. In addition to system flow graphics, provide a system operator information screen.

H. Exhaust Fan Systems. Graphical representation of the EF system. All setpoints to be user-adjustable from this screen. An operator shall be able to view and control (where applicable) the following parameters via the operator interface:

1. Occupancy status
2. Fan command and status
3. Capability to override all fans and dampers.

I. AHU freeze-stat(s) shall be identified, and factory mounted in a location readily accessible by the technician for operation and repair, with manual reset option only.

J. Duct Static Pressure Optimization must comply with ASHRAE 90.1-2013 energy saving requirements at a minimum. The screen shall display airflow graphics and duct pressure readings.

K. Demand Control Ventilation must comply with ASHRAE 62.1-2013 ventilation requirements. At a minimum, the screen shall display airflow graphics, CO2 readings, and outside air damper position.

L. Totalizing

1. A totalizing program shall be provided to enable the building operator to monitor and totalize any user-defined flow such as water flow, electricity, and natural gas.
2. A minimum of 64 totalizing equations shall be provided.

M. Expanded Messages

1. The user shall be able to define a minimum of (10) 40-character messages for automatic printing in the event of system alarm and/or run time and maintenance events.
2. A minimum of 64 totalizing equations shall be provided.

N. Diagnostics

1. The building operator shall be provided with a report containing common symptom and diagnostic trouble shooting guides for HVAC system equipment.

PART 3 - EXECUTION

3.1 EXAMINATION

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

B. Verify that duct and equipment-mounted devices are installed before proceeding with installation.

3.2 INSTALLATION

A. Each equipment shall have a dedicated new DDC controller and must be mounted in a fully accessible manner in a mechanical equipment room or above the ceiling on a wall near the controlled equipment.

B. Interlock wiring cable shall be white color or as coordinated with other trade not to conflict.

C. Smoke detector interlock shutdown wiring cable shall be red color or as coordinated with other trade not to conflict.

D. All DDC network trunk cabling shall be plenum rated cable, purple color with yellow stripe. Cables shall be run parallel and perpendicular to building lines, neatly grouped, supported in all areas, and protected from damage.

E. Interlock shutdown wiring shall be wired directly fail safe from the signaling device to the actuated equipment Integrated Controls and be supported at regular interval. The interlock shutdown signaling device shall also be wired fail safe to the BAS DDC controls.

F. All electrical work performed in the installation of the BAS system, as described in this specification. shall be per the National Electrical Code (NEC) and per applicable state and local codes. All wiring shall be installed in electric metallic tubing (EMT) conduit except as allowed below. Where exposed, conduit shall be run in EMT parallel to building lines properly supported and sized at a maximum of 40 percent fill. In no cases shall field installed conduit smaller than ½ inch trade size be allowed. All electrical work shall comply with Electrical requirements of these specifications.

G. If not indicated on the electrical drawings to be provided by the Electrical Contractor, the BAS Contractor shall be responsible for dedicated ATCS power to closest electrical panel that can support a 120-volt 20-amp breaker.

H. The BAS Contractor is responsible to provide a data drop through Telware. One shall be provided per Global controller. Drops shall be run as soon as location of Global controller(s) has been determined.

I. Do not install Class 2 wiring in conduit containing Class 1 wiring. Boxes and panels containing high voltage may not be used for low voltage wiring except where UL Listed for the purpose of interfacing the two (e.g., relays and transformers).

J. All wire-to-device connections shall be made at a terminal blocks or terminal strip and clearly identified. All wire-to-wire connections shall be at a terminal block. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

K. All wiring shall be installed as continuous lengths, where possible. Any required splices shall be made only within an approved junction box or other approved protective device with each conductor clearly identified.

L. Size of conduit and size and type of wire shall be the design responsibility of the BAS Contractor, in keeping with the manufacturer's recommendation, CMS color code standards, and the NEC.

M. Control and status relays are to be in designated enclosures only. These relays may also be located within packaged equipment control panel enclosures. These relays shall not be located within Class 1 starter enclosures unless UL Listed for the purpose.

N. Adhere to Electrical requirements for installation of raceway.

O. Flexible metal conduits and liquid-tight, flexible metal conduits shall not exceed 3 feet in length and shall be supported at each end. Flexible metal conduit less than ½ inch electrical trade size shall not be used.

P. Mount laminated controls drawings and operational sequences next to the main controller.

Q. Mount the panel specific labelled wiring diagrams inside the main controller. Provide specific termination labeled wiring diagram for each controller. Laminate and adhere to the inside of each individual panel door.

3.3 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Install raceways, boxes, and cabinets according to Electrical requirements.

B. Install building wire and cable according to Electrical requirements.

C. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

D. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

E. Provide comprehensive labeling and tagging of all system components and wiring terminals.

F. Provide engraved laminated tags for every box and cabinet containing devices, controllers, transformers, equipment, and every ceiling access point.

G. Identify raceway junction box covers containing Network Cables with the color purple.

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

1. Verify component inventory, as compared to the submittals.
2. Verify labeling of all DDC controllers, components, access points, terminations, and cable types/colors.
3. Verify wiring connection and integrity (e.g., no loose strands and connections are properly tightened)
4. Verify BACnet trunk bus topography, grounding of shields, and installation of termination devices.

5. Verify each I/O device is landed per the submittals.
6. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
7. Test each point through its full operating range to verify that safety and operating control set points are as required.
8. Verify that analog sensors are properly scaled, and the value is correctly reported to the BAS.
9. Verify that binary sensors have the correct normal position, and the state is correctly reported to the BAS.
10. Verify that analog outputs have the correct normal position and move full stroke when commanded. Confirm position feedback, if applicable, is correctly reported to the BAS.
11. Verify that binary outputs have the correct normal state and respond correctly to energize/de-energize commands. Confirm output state (e.g., ON/OFF, RUN/STOP, etc.) is correctly reported to the BAS.
12. Measure and record voltages.
13. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
14. Functionally test each system for compliance with sequence of operation.
15. Test software and hardware interlocks in both Normal and Fail-Safe modes.
16. Provide seasonal testing while building is occupied in August/September for cooling mode, and December/January for heating mode.

C. DDC Verification:

1. Verify that instruments are installed before calibration and testing.
2. Check instruments for proper location and accessibility.
3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
4. Check temperature instruments and material and length of sensing elements.
5. Check DDC system as follows:
   a. Verify that DDC controller power supply is from emergency power supply, if applicable.
   b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
   c. Verify sequence of operation functional performance.
6. Verify that the systems control, and sequence of operations can be accessed from the graphical interface via the embedded PDF, per specification section 230901.

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

3.5 ADJUSTING

A. Calibrating and Adjusting:

1. After completion of the installation, perform final checkout and adjustments of the equipment provided under this contract and supply services incidental to the proper performance of the BAS system under warranty below.
2. Adjust initial temperature and other set points.
3. See sequence of operation for initial temperature/pressure setpoint values.

B. Provide final time schedule programming during Owner’s training.

3.6 INTEGRATION OF NON-HVAC BUILDING SYSTEMS

A. See Sequence of Operation section on Construction Documents for miscellaneous integration and monitoring requirements to be connected to the BAS.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's Energy Management Staff (PM's and EMS Control Specialists) to adjust, operate, and maintain HVAC instrumentation and controls. Provide a site walk-thru to view the layout and placement of the EMS/BAS System controllers, equipment controlled, integration to equipment, and sensor locations as marked. Provide 16 hours of technical classroom training of the BAS Vendor's system "live" on site or another suitable location to be determined by CMS over a multi-day/week period. The agenda will be defined to include remote access to the completed project's GUI, exercises using diagnostics utilizing all the software and hardware capabilities of the BAS, programming, graphical editing, editing/addition of tags, labels and hyperlinking of points and PDFs.

3.8 SPARE PARTS LIST

A. Controls contractor shall provide spreadsheet bill of materials for each specific component used on the project. Spreadsheet shall be provided as a hyperlink on the BAS front end.

3.9 WARRANTY REQUIREMENTS

A. TWO YEAR WARRANTY: Provide all labor, material, and equipment necessary to maintain beneficial performance of the entire control system for a period of two (2) years after DELIVERY OF THE COMPLETED FLAWLESS GRAPHICAL USER INTERFACE as accepted by no less than two EM/EMS staff members. The BAS Contractor, at no charge to the Owner, shall promptly correct any defects in workmanship or material during the warranty period. All work shall be accomplished during normal working hours M-F, if possible. Precaution shall be taken to minimize disruption of facility operations.

1. Provide an alternate price to extend this warranty to five (5) years.

END OF 230900

SECTION 230901 – BUILDING AUTOMATION SYSTEM GRAPHICAL USER INTERFACE

PART 1 - GENERAL

1.1 INSTRUCTIONS TO VENDORS

A. Vendor is cautioned that the Owner reserves the right to reject any Vendor, which in the Owner's sole judgment, takes meaningful deviation or exception to Division 23 Direct Digital Control (DDC) Standards. The Charlotte-Mecklenburg Schools' (CMS) Energy Manager and/or designated representative of the Energy Management Department (EMD) shall review all vendor substitution submittals. Vendor substitution approval/ disapproval shall be returned via the project architect in writing from Charlotte-Mecklenburg Schools' Energy Manager and designated EMD Project Manager.

1.2 RELATED DOCUMENTS

A. Sections within Division 23 Mechanical apply, including though not limited to:

1. 230900 – Energy Management System and Building Automation System for HVAC and Lighting Control

2. 230902 – BAS Point Naming and Tagging Guideline

1.3 SUMMARY

A. This Section includes the proposed structure of the Charlotte-Mecklenburg Schools Building Automation System Graphical User Interface.

1.4 ABBREVIATIONS AND ACRONYMS

A. AHU: Air Handling Unit

B. GUI: Graphical User Interface

C. IP: Internet Protocol

D. PC: Personal Computer

1.5 SYSTEM PERFORMANCE

A. The GUI shall be accessible by entering individual unique user ID's and passwords with varying levels of administrator functionality from any IP connected user device without the need for special software or a dedicated PC.

B. Navigation shall be via point and click mouse selection and keyboard entry by personnel requiring little or no formal training.

C. A navigation tree shall be provided for selection of Graphics being pulled up by School name, listed in descending Alphabetical Order with an initial Summery Graphic at the top of the Tree Listing all Schools by Grade. Subgroups by grade and/or building function shall also be provided.

D. Selecting subsequent branches for each school shall depict the individual Schools GUI Summary Page showing the Site Plan for the School's entire Campus Buildings in a dynamic key plan to allow the user to drill down to further levels of zoom and sub-branches from the tree.

E. Zoom of plan GUI screens shall be either mouse wheel or subsequent point-and-click levels of plan drawings to provide the sufficient level of details. The layout and structure for all equipment and subsequent devices should be consistent for both enumeration and format regardless of vendor.

F. All GUI plan drawings shall be oriented so that the front of the school's main entrance is at the bottom of the page. All subsequent levels of zoom for floor plans shall retain the same orientation.

G. All GUI screens shall be titled on every page in sequence by the School Courier Code; Formal assigned Name; and further branches down the tree by Type of major piece of equipment; Individual Device; separated by hash marks. Each School's initial Summary page shall also provide the US Postal Address of the building in its entirety and an orientation indicator to due North.

H. School summary page should also show Primary Central Plant equipment status and primary AHU's general status with site wide combined selected high-level alarms status. Hyperlinks shall be provided to allow for global parameters to be set, monitored, and modified.

I. Subsequent branches down from the school summary page shall depict the Building(s), then Floor Plans from lowest elevation to the highest elevation, including lofts and Mezzanines. The geographic location of every major monitored, and controlled piece of equipment placed in its physically installed position shall be shown on overlays of the site/floorplan and/or riser/line diagrams by School. The building overall floor plans shall also show each individual space temperature with relevant thermographic color infills depicting space actual temperature in relation to setpoints. Color indicators shall be as follows: Green = within setpoint range, Blue = cooler than setpoint range, Red = warmer than setpoint range. Colors out of range shall show in 2°F gradients. Deeper colors of Red and Blue shall show the greatest range deviations from setpoints.

J. All building floor plans used for GUI base drawings must show all fixed structural elements, doors, room designations, stairs, and shaftways. Mechanical background drawings showing equipment locations such as AHU, VAV, and associated ductwork are preferred.

K. Subsequent branches drilling down into major pieces of equipment shall depict sub-component and end-of- line devices in their geographic position within a room and/or in proper alignment on equipment pictographs as installed over layered one- line flow diagrams, mechanical floorplan details, or the detailed equipment graphics.

L. Tree Layout. The navigation tree consists of tabs that contain nodes, legible display text, graphical links, and icons. It shall be assembled and built by choosing display text for nodes, arranging the nodes, and assigning associated graphics to them.

M. Branch Layout. Shall be arranged first by School Site, then by Building, then by Floor and further, if necessary, by Room. Branches shall also be provided for diagnostic and programming tables for individual equipment for use by technicians.

N. All branches shall be constructed in a consistent logical, flow and format as follows:

1. First Branch: The CMS name and courier address of the campus grouped by grade in descending
   alphabetical order; (Linked to sites Summary Page /Campus Overview.)
2. Second Branches: ALL Sub-buildings number/letter within a Campus (where applicable); (Linked to Ground Level Elevation of the selected building.)
3. Third Branches: ALL Individual elevations of the building including Roof Elevations; (Linked to specific elevation.)
4. Fourth Branch: Spaces (by Room number based on the designation from the architectural plans.)
5. Subsequent Branches: Sub-branches of Central Plants, grouped equipment and components with navigation links to upstream/downstream system components; Relevant links to troubleshooting aids, setpoints and PDFs; (Linked to individual specific components and/or Central Plants.)

O. BAS Global Navigation Task Bar. Provide task bar for Global Set Points, Alarm, User, Admin and Help Functions queries. Global Navigation shall be at the top of the tree and transfer data to and from all subsequent branches of the tree.

P. System Navigation Links: Provide links to point's status, graphics, data logs, alarms and events, equipment, spaces, systems, points, schedules, reports, tools.

Q. All equipment IDs shall be enumerated based on a sequence starting from left to right with the major equipment type abbreviation, floor elevation, then the specific units building zone and/or room number. Dedicated pumps and fans shall be enumerated with the same numerical designation as the major equipment upstream that the pump or fan serves. If more than one of the same types of pumps or device exists in parallel, an alpha character shall also be sub-assigned to differentiate each device. Where multiple rooms are served by a single piece of equipment, the area containing the controlling device shall dictate the primary upstream equipment's unique enumeration.

R. All equipment down to the end line devices shall be clearly identified with sufficient branches, zoom, and scale to make it clear to the operator specifically where in a building or room the equipment is physically located relevant to the building drawings.

S. All relevant documentation derived from installation, including operational design parameters, sequences, point-to-point wiring diagrams, device catalog cutsheets, plan mechanical drawings, riser drawings, device details, maintenance manuals, and repair procedures shall be segregated then embedded with a point-and-click navigation from the Site Summary Page and/or the lowest zoom level where the depicted device resides.

T. For each piece of equipment, a GUI screen hyperlink shall be provided to display a drill down screen showing the technical parameters of the device for troubleshooting and diagnostics.

U. The layout for every GUI screen shall be consistent for each like piece of equipment regarding positioning of relevant information. The one-line diagram and flow of Central plant piping shall be as close as possible to a direct representation of actual field conditions.

V. The grouping of GUI parameters for each screen shall be consistent throughout all similar screens for ALL schools.

1.6 SUBMITTALS

A. Product Data: Include manufacturer's examples of graphics for type of system indicated.

1. Control System Software: Include technical data for operating system software, operator interface, color graphics, programming, sequence of operations, and other third-party applications.

PART 2 – PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 WARRANTY REQUIREMENTS

A. TWO YEAR WARRANTY: Provide all labor, material, and equipment necessary to maintain beneficial performance of the entire control system for a period of two (2) years after DELIVERY OF THE COMPLETED FLAWLESS GRAPHICAL USER INTERFACE as accepted by no less than two EM/EMS staff members. The BAS Contractor, at no charge to the Owner, shall promptly correct any defects in workmanship or material during the warranty period. All work shall be accomplished during normal working hours M-F, if possible. Precaution shall be taken to minimize disruption of facility operations.

1. Provide an alternate price to extend this warranty to five (5) years.

END OF 230901

SECTION 230902 – BAS POINT NAMING AND TAGGING GUIDELINE

PART 1 - GENERAL

1.1 INSTRUCTIONS TO VENDORS

A. Vendor is cautioned that the Owner reserves the right to reject any Vendor, which in the Owner's sole judgment, takes meaningful deviation or exception to Division 23 Direct Digital Control (DDC) Standards. The Charlotte-Mecklenburg Schools' (CMS) Energy Manager and/or designated representative of the Energy Management Department (EMD) shall review all vendor substitution submittals. Vendor substitution approval/disapproval shall be returned via the project architect in writing from Charlotte-Mecklenburg Schools' Energy Manager and designated EMD Project Manager.

B. The overriding requirement is the use of the DDC Control System to maintain design occupant comfort with optimal minimized energy consumption while maximizing equipment, component, and system design function integrity and life.

1.2 RELATED DOCUMENTS

A. ASHRAE Standard 135 (latest version)

B. Sections within Division 23 Mechanical apply, including though not limited to:

1. 230800 – Commissioning of HVAC
2. 230900 – Energy Management System and Building Automation System for HVAC and Lighting Control
3. 230901 – BAS Graphical User Interface Guidelines
4. 230923 – Control Valves
5. 234320 – Air Purification System

1.3 SUMMARY

A. An individual piece of equipment should have the same name convention regardless of where in the system the points may be defined. There should be one and only one standard point name for each distinct point and type. Abbreviations of complete point names will be permitted for GUI displays when the point's geographic location is obvious on the graphic depicted.

B. An equipment point name combination should uniquely identify the piece of equipment and its geographic location in a building with the complete and unambiguous context of the point.

1.4 EQUIPMENT

A. Equipment names should be unique-and sequenced to follow a consistent logical flow and order based on its geographic location within a School. The order of the equipment name shall be: Three-digit School courier number; Building/Elevation; Room number; Equipment Type; Specific Connected Device Identification. Note the following examples:

1. (XXX-A1-CR123-AHU-01-SF) XXX=School Courier Code, A1=Building "A" First Floor, CR123=ClassRoom123, AHU-01=Air Handler Unit #1, SF= Supply Fan
2. (XXX-M2-CR208-FC-01) XXX=School Courier Code, M2=Building "M" Second Floor, CR208=Classroom 208, FC-01=Fan Coil Unit #1
3. (XXX-MSB-BR20-BL-01-PriPmp-01) XXX=School Courier Code, MSB=Building "M"

Sub-Basement, BR20=Boiler Room 20, PriPmp01=Primary Pump #1.

B. Equipment represented by a device on a bus should have a unique folder name in the BMS path. The School Courier Code and full name shall be used if possible.

C. Equipment sequence numbers should always be at the end of the equipment name with no additional underscore. Dedicated pumps for upstream Equipment, such as Boilers and Chillers, shall maintain the same designation as the Boiler or Chiller served. Dedicated Equipment, such as VAVs connected to AHUs, shall be enumerated with the same designation as the upstream equipment hyphenated by the room served designation. Note the following examples:

1. (XXX-MSB-BR20-BL-01-PriPmp-01) XXX=School Courier Code, MSB=”M” building Sub-Basement, BR20=Boiler Room#20, Boiler “#1” shall have the Primary Pump designated PriPup “#1.”

2. (XXX-A1-CR123-VAV-01-123A) XXX=School Courier Code, A1=”A” Building First Floor, Classroom 123, VAV in Room 123 is from AHU-01.

D. Trailing Sequential Alphabetic characters should be placed at the end of the sequence number for uniquely identifying multiple parallel equipment that services the same VAV or piece of equipment. Note the following examples:

1. (XXX-MSB-BR20-BL-01-PriPmp-01A) and (XXX-MSB-BR20-BL-01-PriPmp-01B) represent two pumps in parallel servicing the Primary Loop for Boiler #1.

2. (XXX-A1-CR123-VAV-01-123A) and (XXX-A1-CR123-VAV-01-123B) represent two VAV’s in Room 123 supplied from AHU 01

E. Equipment software points defined in separate control routines should use the same unique name at the beginning of the point name followed by an underscore.

F. Equipment names should follow the standard abbreviations with a hyphen between unique sequential characters (See STANDARD ABBREVIATIONS Tables). If more than ten units of the same equipment ID number are utilized a preceding zero shall be used. Note the following examples:

1. AHU-01, AHU-10.

2. Blr-01, Chlr-02

3. CHP-1A, HWP-1A, BCHP-1A, BHWP-1A

4. FCU-(Room number served by the FCU).
   a. If multiple rooms are served by the FCU, use the room number in which the thermostat is located.
   b. If multiple FCU’s serve the same room, add an alpha character to designate (FCU-215A/B).

5. UV-(Room number served by the UV).
   a. If multiple rooms are served by the UV, use the room number in which the thermostat is located.
   b. If multiple UV’s serve the same room, add an alpha character to designate (UV-215A/B).

6. EF-(Space number served by the EF).
   a. If multiple spaces are served by the EF, use the space number in which the thermostat and/or switch is located.
   b. If multiple EF’s serve the same space, add an alpha character to designate (EF-215A/B).

1.5 POINTS

A. Point names should follow the standard abbreviations.

B. Point name compounds should progress from left to right, most general to the left and most specific to the right.

1. Example: SaTemp, SaTempSp, SaPress, SaPressSp, RaHum, RaDeHumidifySp,

1.6 HISTORIES

A. History names should be generated using the Niagara Bformat strings %parent.name% whenever possible.

B. History names should progress from left to right, most general to the left and most specific to the right.

C. The general format is: 3-digit Courier ID XXX, EquipName, SubEquipName, PointName, PointAttribute. Note the following examples:

1. XXX_AHU01_SaFanCmd, AHU01_SaFanSpd, AHU01_SaFanSts

2. XXX_AHU02_ChWVlvPos,

3. XXX_Blr01_BlrEnab, XXX_Blr01_BlrIsoVlvCmd, XXX_Blr01_BlrCPCmd, XXX_Blr01_BlrETemp, XXX_Blr01_BlrLTemp

4. XXX_Chlr01_ChlrEnab, XXX_Chlr01_ChlrIsoVlvCmd, XXX_Chlr01_ChlrCPCmd, XXX_Chlr01_ChlrETemp, XXX_Chlr01_ChlrLTemp

5. XXX_CHWS_SupTemp, XXX_CHWS_RetTemp, XXX_CHWS_ChWP01_ChWPCmd, XXX_CHWS_ChWP01_ChWPVFDSpd, XXX_CHWS_ChWP02_ChWPSts

6. XXX_MZ01_Zn03_SpcTemp, XXX_MZ01_Zn03_SpcTempEffSp

7. XXX_HWS_SupTemp, XXX_WS_SupTempSp, XXX_HWS_HWRetTemp, XXX_HWS_HWP01_HWPCmd, XXX_HWS_HWP01_HWPSpd

1.7 STANDARD TERMS

A. Air Purification System (Needle Point Bi-Polar Ionization): Installed as a stand-alone device within an air handling unit, terminal unit, or associated ductwork.

B. Circulation (Pump): A pump typically within the plant that circulates a fluid through an individual piece of equipment such as a chiller, boiler, domestic water heater, cooling tower or heat exchanger. Associated with primary, secondary or recirculation hydronic loops.

C. Chilled Water System: A hydronic cold-water loop with various BAS controls to provide constant or variable temperatures where global points related to the overall chilled water plant are defined. Points would include loop entering/leaving temperatures, setpoints, loop pumps, valves, differential pressures and other global points not necessarily located within the Central Plant. This should match Hot Water System.

D. Command: Indicates a piece of equipment, valve, damper, or fan has been command to a Boolean value of on/off or open/close. (See Enabled, Status and Position for related points)

E. Effective: Indicates the current temperature or pressure setpoint target given the current mode of operation. For a temperature or flow set point this value would change as a piece of equipment moves between occupied and unoccupied and heating and cooling modes.

F. Enabled/Disabled: A Boolean software point indicating an equipment's local/embedded controller is being enabled and should provide a physical output change in state to start/stop local control. It does not indicate a piece of equipment is running or not running. Points within the local controller must be monitored to indicate the actual running state. Enabled/Disabled should never be used to indicate the commanding of a point or piece of equipment on or off. (See Command and Status for related points)

G. Energy: Tracks the consumption of a unit of energy (kWh, btu, etc.). Always an accumulated value with a totalized tag.

H. Exhaust: Indicates undesired air leaving the building due to contaminants or other undesirable components like excess heat or humidity. Common areas would include bathrooms, mechanical areas, dryers, pools, and laboratories.

I. History Intervals: Numeric history intervals for new projects with newer controllers and adequate memory should be 10 minutes or Change Of Value (COV). Retrofit work should correspond with the existing intervals. In all cases the history interval should be the same for all points on a piece of equipment so that histories align on the same time boundaries.

J. Frequency: Frequency is a range of numeric values either commanding or sensing a VFD running at a specific Hz during a slice in time. See Speed for VFD percent control.

K. Hot Water System: A hydronic hot water loop with various BAS controls to provide constant or variable temperatures. Points would include loop entering/leaving temperatures, setpoints, loop pumps, valves, differential pressure sensors, enabling values and other global points. not necessarily located within the Central Plant.

L. Pumps should be designated as either Primary, Secondary, or Recirculation. “Loop” designation should not be used as it is uncommon and non-specific.

M. Makeup Air Unit: An air handler that takes in outside air and heats, cools, humidifies, or dehumidifies for delivery to the building with no recirculation. May be a preheat unit to an AHU or general discharge into the building.

N. Mixed Air Damper: Mixed air damper should only be used when there is a specific third damper controlling mixed air separate from the outside air damper and the return air damper. An electronically linked two damper configuration of outside and return air dampers should never name the two dampers as a mixed air damper.

O. Mode: A software point indicating the current operating intent of a piece of equipment. Used to understand the current system mode (i.e., Occupancy, Humidify, Dehumidify, Economizing, IAQ, Heating, Cooling, etc.) when analyzing related points.

P. Occupancy: A state of physical presence within a building space that is detected by a device or produced by a Boolean point indicating a unit is in occupied or unoccupied mode.

Q. Phase: Indicates electrical attributes (amps, volts, power, or energy) as measured across an individual phase. A string value containing A, B, C; AB, BC, AC; or AN, BN, CN.

R. Power: Tracks the instantaneous value of power (kW, btu/h, etc.).

S. Position: A numeric value indicating a valve or damper open position between 0% (Closed) and 100% (Open).

T. Preheat: Preheat indicates heating coils and valves intended to heat outside air to prevent the freezing of cooling coils. Often seen in cold climates with minimum outside air damper positions or large outside air requirements.

U. Primary: The primary tag is always used in the context of the site. Primary refers to piping, valves, pumps and sensors within the heating/cooling plant that moves water between a specific piece of equipment in the central plant. Common primary equipment includes individual chillers, boilers, heat exchangers, isolation valves, pumps, and sensors.

V. Radiant: Indicates hot or cold water radiant heating or cooling systems

W. Relief: Indicates a point at which excess air is leaving the building to maintain overall building static pressure and/or indoor air quality. Most commonly associated with the air handling units.

X. Room: A specific area referenced based on architectural floor plans. This term should not be used. Use "Space" instead to represent any specific area ventilated by mechanical equipment derived from the architectural floor plans.

Y. Secondary: The secondary tag is always used in the context of the site. Secondary refers to equipment or points moving air or fluids away from one or more individual primary source(s) to another area for use. Common sources may include chilled water or hot water plants within a building or a central or district plant on a campus. Common uses may include campus distribution of chilled water, hot water, or steam; or chilled, hot, domestic water loops which are not passing directly through primary equipment within a building. (e.g., Secondary Dual Temperature Pumps)

Z. Space: Space is the general term used to define an airtight compartmentalized indoor area ventilated by mechanical equipment such as AHUs, VAVs, UVs, and FCs including ancillary Supply and Exhaust Fans and influencing ventilated equipment such as Boilers drawing air from a space. The term “Room” or "Zone" should not be used.

AA. Speed: A numeric value commanding a fan or pump to run at a percentage of capacity from 0% (Stopped) to 100% (Full speed.)

BB. Status: A Boolean point indicating proof a commanded action happened. Typically based on an input measure of flow (air, water, current) resulting from the change in state of a field devices physical reaction. Boolean Status should never be used to indicate the commanding of a point on or off. (See Command and Enabled for related points)

CC. Zone: While "zone" is the haystack tag for a space or room, point naming should use the term "space.” See Space.

DD. Total: Indicates the total power or energy across all phases of electricity.

1.8 SUBMITTALS

A. Provide summary list of BAS Controls Points following the requirements of this specification.

1. Summary list shall follow format or energy across all phases of electricity.

PART 2 - PRODUCTS

2.1 STANDARD ABBREVIATIONS

A. Specific Tags can be formulated using multiple grouped abbreviations from below starting with the equipment type designation then using underscores to drill down to the specific device function (VAV_102_Spc_Temp).

TERM	ABBREVIATION
Air	Air/a
Air Handler Unit (equip)	AHU

Air Purification System (Needlepoint Bi-Polar Ionization)	NPBI
Alarm	Alrm
Average	Avg
Current (Amps)	Amp
Backdraft Damper	BDD
Boiler (equip)	Blr
BTU	BTU
Building	Bldg
Bypass	Byp
Cabinet Unit Heater	CUH
Central Exhaust Fan (equip)	CEF
Carbon Dioxide	CO2
Carbon Monoxide	CO
Chilled Water	ChW
Chilled Water System	CHWS
Chiller (equip)	Chlr/Chl/Chr
Circulation Pump (individual equipment)	CP
Cold Deck	CD
Command (Open/Closed/On/Off)	Cmd
Condenser Water	CW
Cooling Coil	CC
Cooling Tower (equip)	CT
Change of Value	COV
Damper	Dmpr
Day	Day
Dedicated Outside Air System	DOAS
DeHumidify (setpoint/enabled/mode)	DeHumidify
Dew Point	DewP
Differential Pressure	DP
Differential Temperature	DT
Discharge Air	Da
Discharge Air Fan	DaFan
Domestic Hot Water System	DHW
Dryer	Dryer
Dryer Exhaust Fan (equip)	DEF
Duct	Duct
Economize (enabled/mode)	Econ
Effective	Eff
Enable	Enab
Entering	Ent

Enthalpy	Enth
Exhaust Fan (equip)	EF
Exhaust Air	Ea
Exhaust Air Fan	EaFan
Evaporative Unit	EVAP
Fan (use pre qualifier: Sa, Ra, Ea)	Fan
Fan Coil Unit (equip)	FCU
Filter	Fltr
Flow	Flow
Freeze	Frz
Frequency	Freq
Fuel Oil	FO
Gallons	Gal
Glycol	Gly
Heat Exchanger (use qualifiers: Stm, ChW)	Hx
Heat Recovery Unit (equip)	HRU
Heating Coil Hydronic	HC
Heating Coil Electric	HCE
High	High/Hi
Hot Deck	HD
Hot Water	HW
Hot Water System	HWS
Hour	Hr
Humidify (setpoint/enabled/mode)	Humidify
Humidity (assumed relative)	Hum
Indoor Air Quality (mode)	IAQ
Interval	INT/int
Isolation	Iso
Kilowatts (power)	kW
Kilowatt Hours (energy)	kWh
Leaving	L/Lv
Level	Lvl
Limit	Lmt
Load	Load
Low	Low/Lo
Makeup Air Unit (equip)	MAU
Maximum	Max
Medium	Med
Millions BTU	MBTU
Minimum	Min

Mixed Air	Ma
Mixing (Valve)	Mix
Mode	Mode
Month	Mo
Multi Zone (equip)	MZ
Occupancy/Occupied	Occ
Outside Air	Oa
Perimeter	Per
Phase	Ph A/B/C
Position (%)	Pos
Power Factor	PF
Preheat (equip)	Preheat
Preheat (points)	PH
Preheat Coil	PHC
Pressure (assumed static)	Press
Primary	Pri
Pump	Pmp
Radiant Heat	Rad
Reheat	Reheat/RH
Relief / Return Relief	Rlf
Return	Ret
Return Air	Ra
Return Air Fan	RaFan
Room	Rm
Rooftop Unit	RTU
Runtime	Run
Secondary	Sec
Setpoint	Sp
Space	Spc
Speed	Spd
Stage(s)	Stg(s)
Standby	Stby
Start/Stop	S/S
Static Pressure	Press
Status	Sts
Steam	Stm
Supply	Sup
Supply Air	Sa
Supply Air Fan	SaFan
Temperature	Temp/T
Tons	Ton

Tons Refrigerant	TonRef
Total	Tot
Unit Heater (equip)	UH
Unit of Measure	UoM
UnOccupied	Unocc
VAV (equip)	VAV
VAV Cooling Only	VAVCO
VAV Heating Only (Dual Duct)	VAVHO
VAV with Reheat	VAVRH
Valve	Vlv/V
Variable Frequency Drive	VFD
Variable Refrigerant Flow/Volume	VRF
Ventilator Fan (equip)	VF
Volts	Volt
Volume	Vol
Water	Wtr/W
Week	Wk
Year	Yr
Zone (multi zone equip)	Zn

END OF 230902

SECTION 230923 – CONTROL VALVES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes control valves and actuators for DDC systems.

B. Related Requirements:

1. Section 230719 “HVAC Piping Insulation” for requirements that relate to valve insulation.

2. Section 230900 “Energy Management System and Building Automation System for HVAC and Lighting Control” for requirements that relate to wire and cable.

3. Section 230901 “BAS Point Naming and Tagging Guideline” for requirements that relate to valve tagging.

C. Control valves shall not be used as manual isolation or service valves. Use appropriate full port valves for equipment and sectional header isolation.

D. Actuators for Fire Suppression Systems shall be NFPA rated for Fire Service

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Shop Drawings:

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

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 drop across valve at project design flow condition.
   c. Pressure drop across valve at minimum flow condition.
   d. Maximum system pressure differential drop (pump close-off pressure) across valve at project minimum flow condition.
   e. Design control valve coefficient with corresponding valve position.
   f. Maximum close-off pressure.
   g. Leakage flow, if any, at maximum system pressure differential.
   h. Torque required at worst case condition for sizing actuator.
   i. Actuator selection indicating torque provided.

1.3 CLOSEOUT SUBMITTALS

A. Operation and Maintenance (O&M) Data

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. Ground Fault: Products shall not fail due to ground fault condition when suitably grounded.

D. Determine control valve sizes and flow coefficients by ISA 75.01.01.

E. Control valve characteristics and rangeability shall comply with ISA 75.11.01.

F. Insulation Requirements for all valve bodies shall comply with Pipe Insulation under 230719. Insulation on all actuator valve bodies shall be constructed to be water resistant and removable for servicing and repair. The removable section shall be constructed so as not interfere with actuator or linkage operation and provided fasteners for reinstallation without the need for any additional material or tools.

G. Selection Criteria:

1. Control valves shall be suitable for operation at following conditions:
   a. Chilled Water: 40 to 60 °F and 50 psig
   b. Heating Hot Water: 40 to 200 °F and 50 psig

2. Fail positions unless otherwise indicated:
   a. Chilled Water: Last position
   b. Heating Hot Water: Open

3. Apply Cv correction factors for piping geometry as required by valve manufacturer or as required by ISA 75.01.01. Correction factor can be ignored if effect is less than 10% of rated value.
4. In water systems, select modulating control valves at terminal equipment for a design Cv based on a pressure drop of 5 psid, or the pressure drop of the coil at design flow, whichever is greater, unless otherwise indicated.
5. Control valve assemblies shall be provided and delivered from a single manufacturer as a complete assembly.
6. The manufacturer shall warrant all components for a period of 5 years from the date of production with the first two years unconditional.

2.2 BALL-STYLE CONTROL VALVES

A. Ball Valves with Single Port or Characterized Disk:

1. Pressure Rating for NPS 1-1/4 and Smaller: Nominal 600 psig
2. Pressure Rating for NPS 1-1/4 through NPS 2: Nominal 400 psig
3. Pressure Rating for NPS 2-1/2 through NPS 6: In accordance with ANSI 125, Class B
4. Close-off Pressure NPS 2 and Smaller: 200 psig
5. Close-off Pressure NPS 2-1/2 through NPS 6: ANSI Class 125B: 175 psid; ANSI Class 250: 310 psid.
6. Process Temperature Range: 0 to 250 °F
7. Body and Tail Piece NPS 2 and Smaller: Nickel plated (forged) brass
8. Body and Tail Piece NPS 2-1/2 through NPS 6: Cast iron GG25
9. End Connections NPS 2 and Smaller: Threaded (NPT) female ends
10. End Connections NPS 2-1/2 through NPS 6: Flanged ANSI Class 125B
11. Ball NPS 3/4 and Smaller: Chrome-plated brass
12. Ball NPS 1 through NPS 6: Stainless steel
13. Stem and Stem Extension:
    a. Material to match ball
    b. Blowout-proof design

14. Ball Seats: PTFE (Tefzel), EPDM O-rings
15. Stem Seal: Lubricated EPDM O-rings
16. Characterizing Disc NPS 2 and Smaller: Tefzel
17. Characterizing Disc NPS 2 through NPS 6: Stainless steel.

18. Flow Characteristic: Equal percentage
19. Leakage: 0%

B. Ball Valves with Two Ports and Characterized Disk:

1. Pressure Rating for NPS 1-1/4 and Smaller: Nominal 600 psig
2. Pressure Rating for NPS 1-1/4 through NPS 2: Nominal 400 psig
3. Close-off Pressure: 200 psig
4. Process Temperature Range: 0 to 250 °F
5. Body and Tail Piece: Nickel plated (forged) brass
6. End Connections: Threaded (NPT) female ends
7. Ball NPS 3/4 and Smaller: Chrome-plated brass
8. Ball NPS 1 through NPS 6: Stainless steel
9. Stem and Stem Extension:
   a. Material to match ball
   b. Blowout-proof design
10. Ball Seats: PTFE (Tefzel), EPDM O-rings
11. Stem Seal: Lubricated EPDM O-rings
12. Flow Characteristics for A-Port: Equal percentage
13. Flow Characteristics for B-Port: Modified for constant common port flow
14. Leakage (control port): 0%

C. Pressure-Independent Ball Valves NPS 2 and Smaller:

1. Performance:
   a. Pressure Rating for NPS 3/4 and Smaller: 360 psig
   b. Pressure Rating for NPS 1 through NPS 6: In accordance with ANSI 125, Class B
   c. Close-off pressure for NPS 3/4 and Smaller: 75 psig
   d. Close-off Pressure NPS 2 and Smaller: 200 psig
   e. Close-off Pressure NPS 2-1/2 through NPS 6: ANSI Class 125B: 175 psid; ANSI Class 250: 310 psid
   f. Process Temperature Range for NPS 3/4 and Smaller: 36 to 212 °F
   g. Process Temperature Range for NPS 6 and Smaller: 14 to 250 °F
   h. End Connections NPS 2 and Smaller: Threaded (NPT) female ends
   i. End Connections NPS 2-1/2 through NPS 6: Flanged ANSI Class 125B
2. Body for NPS 2 and Smaller: Forged brass, nickel plated, and with threaded ends
3. Body for NPS 2-1/2 through NPS 6: Cast iron GG25
4. Ball: Stainless steel
5. Stem and Stem Extension: Stainless steel, blowout-proof design
6. Ball Seats: PTFE (Tefzel), EPDM O-rings
7. Stem Seal: Lubricated EPDM O-rings
8. NPS 3/4 and Smaller: An integral pressure regulator located upstream of characterized ball to regulate pressure, to maintain a constant pressure differential over the operating pressure differential range of 5 to 50 psig maintaining the flow with an accuracy of ± 5% due to system pressure fluctuations. Two internal P/T ports shall be incorporated for differential pressure verification. Replaceable cartridges are not permitted.
9. NPS 6 and Smaller: An ultrasonic flow meter (accuracy ± 2%) shall be integrated with a characterized control valve providing analog flow feedback. The valve shall reposition to maintain the required flow with a ± 5% accuracy over a pressure differential range of 1 to 50 psig. The flow meter shall incorporate an algorithm to automatically compensate for the glycol compensation.
10. Control valve shall be equal percentage flow characteristic, other than where noted as a linear flow characteristic. Flow settings shall be field-modifiable and may be modified inline.
11. Coil Optimization: Two immersion temperature sensors for supply and return coil water temperatures shall be incorporated into the valve assembly. Software shall control the valve

to avoid the coil differential temperature from falling below a programmed setpoint. Real-time data and configuration of valve operating parameters shall be available by BTL listed BACnet MS/TP, BACnet/IP, MODBUS or HTTP. Monitored points shall include inlet and outlet coil water temperatures, absolute flow, absolute valve position, absolute coil power and total heating/cooling energy in BTU/hr. Configuration points shall include valve, flow, and power settings. Historical trend data shall be stored for up to 13 months and be retrievable in a standard date-time stamped format.

2.3 BUTTERFLY-SYLE CONTROL VALVES

A. Commercial-Grade, Two-Way Butterfly Valves:

1. Performance:
   a. Bi-directional bubble tight shutoff at 250 psig
   b. Comply with MSS SP-67 or MSS SP-68
   c. Rotation: 0 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
   b. Comply with MSS SP-67 or MSS SP-68
   c. Rotation: 0 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 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.
6. Seats and Discs: NBR or PTF
7. Solenoid Enclosure: NEMA 250, Type 4

2.5 ELECTRIC AND ELECTRONIC CONTROL VALVE ACTUATORS

A. Agency Listings: ISO 9001, UL 873 or UL 60730, CE and CSA.

B. The valve assembly (valve and actuator) shall be provided and delivered from a single manufacturer.

C. The manufacturer shall warrant all components for a period of 5 years from the date of production with the first two years unconditional.

D. Actuators for Hydronic Control Valves: Capable of closing valve against system pump shutoff head.

E. Type: Motor operated, with or without gears, electric and electronic.

F. Voltage: Voltage selection delegated to professional designing control system.

G. Deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.

H. Function properly within a range of 85 to 120% of nameplate voltage.

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. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for 0-10 VDC or 4-20 mA signals.
   b. 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 modulating actuators with position feedback through voltage signal for remote monitoring. (e.g., VAV damper, hydronic valve position, non-safety related indication only applications where other feedback sensors are available)
2. 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. Mechanical spring return mechanism to drive controlled device to an end position (open or close) on loss of power.
3. Electronic fail-safe shall incorporate an active balancing circuit to maintain equal charging rates among the Super Capacitors. The power fail position shall be proportionally adjustable between 0 to 100% in 10-degree increments with a 2 second operational delay.

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. Attach actuator to valve drive shaft in a way that ensures maximum transfer of power and torque without slippage.
2. Actuators shall be capable of being mechanically and electrically paralleled to increase torque if required.
3. V-bolt dual nut clamp with a V-shaped toothed cradle; directly couple and amount to the valve bonnet stem, or ISO-style direct-coupled mounting pad.

P. Temperature and Humidity:

1. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of -20 to 120 °F.
2. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from 5 to 95 %RH, non-condensing.

Q. Enclosure:

1. Suitable for ambient conditions encountered by application.
2. NEMA Type 1 for indoor installation in an equipment enclosure.
3. NEMA Type 2 for indoor and protected applications.
4. NEMA Type 4 or Type 4X for outdoor and unprotected applications.
5. Provide actuator enclosure with heater and control where required by application.

R. Stroke Time:

1. Select operating speed to be compatible with equipment and system operation.

PART 3 - EXECUTION

3.1 CONTROL VALVE APPLICATIONS

A. Control Valves:

1. Select control valves to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.
2. Unless otherwise noted, select valves as follows:
   a. Pressure-independent ball valves for systems controlled with VFDs.
   b. Ball valves with single port and characterized disk for all NPS 3” and smaller.
   c. Flanged ball valves or butterfly valves, as required, for sizes larger than NPS 3” or outdoor chiller plant operation.

3.2 INSTALLATION

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. Pipe wrenches, pliers, and other grooved 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 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.

3.3 ELECTRIC POWER

A. Furnish and install electrical power to products requiring electrical connections.

3.4 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 drop-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 4.

E. Install pressure/temperature taps in piping upstream and downstream of each control valve larger than NPS 2".

F. Valve Orientation:

1. Install valves with actuators per manufactures recommendations for the specific application.
2. Where possible, ball valves that are installed in horizontal piping shall be installed with stems upright and not more than 15 degrees from vertical, not inverted.
3. Install valves in a position to allow full stem movement.
4. Where possible, butterfly valves that are installed in horizontal piping shall be installed with stems in horizontal position and with low point of disc opening with direction of flow.

G. Clearance:

1. Locate valves for easy access and provide separate support of valves that cannot be handled by service personnel without hoisting mechanism.
2. Install valves with at least 12 inches of clear space around valve and between valves and adjacent surfaces.
3. Assure actuator indicators are visible.

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.
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.

J. Connect electrical devices and components to electrical grounding system.

K. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same cable designation at each end for operators to determine continuity and the unique wire designations to match points of connection.

L. Install engraved phenolic nameplate with valve identification on valve.

3.5 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. Verify that control valves are installed correctly for flow direction.

5. Verify that valve body attachment is properly secured and sealed.
6. Verify that valve actuator and linkage attachment are secure.
7. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
8. Verify that valve ball, disc, and plug travel are unobstructed.
9. 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.

3.6 ADJUSTMENT, CALIBRATION, AND TESTING

A. Stroke and adjust control valves following manufacturer's recommended procedure, from 100% open to 0% (closed) back to 100% open.

B. Check and document open and close cycle times for applications with a cycle time of less than 30 seconds.

C. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

END OF 230923

SECTION 232113 – HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section includes pipe and fitting materials and joining methods for the following:

1. Hot-water heating piping
2. Chilled-water piping

1.3 ACTION SUBMITTALS

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

1. Pressure-seal fittings
2. Chemical treatment

B. Qualification Data: For Installer

C. Welding certificates

D. Field quality-control reports

1.4 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.

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. Hot-Water Heating Piping: 200 psig at 200 °F
2. Chilled-Water Piping: 125 psig at 90 °F
3. Dual-Temperature Heating and Cooling Water Piping: 200 psig at 200 deg °F

2.2 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type L

B. Annealed-Temper Copper Tubing: ASTM B 88, Type K

C. DWV Copper Tubing: ASTM B 306, Type DWV.

D. Copper or Bronze Pressure-Seal Fittings:

1. Housing: Copper.
2. O-Rings and Pipe Stops: EPDM
3. Tools: Manufacturer's special tools
4. Minimum 200-psig working-pressure rating at 250 °F

E. Copper, Mechanically Formed Tee Option: For forming T-branch on copper water tube

F. Wrought-Copper Unions: ASME B16.22

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" section.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in "Piping Applications" section.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" section.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" section.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; raised ground face, and bolt holes spot faced as indicated in "Piping Applications" section.

F. Wrought-Steel Fittings: ASTM A 234, wall thickness to match adjoining pipe

G. Wrought Cast and Forged Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1
2. End Connections: Butt welding
3. Facings: Raised face

H. Steel Pressure-Seal Fittings:

1. Housing: Steel
2. O-Rings and Pipe Stop: EPDM
3. Tools: Manufacturer's special tool
4. Minimum 300-psig working-pressure rating at 230 °F

I. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.4 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8" maximum thickness, unless otherwise indicated.
   a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges
   b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated

C. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

D. Brazing Filler Metals: AWS A5.8, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

E. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

F. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

2.5 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: 150 psig at 200 deg °F
   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: 150 psig at 200 deg °F
   d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint 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 at 200 deg °F
   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 F 1545
   c. Pressure Rating: 150 psig at 200 deg °F
   d. End Connections: Male threaded or grooved
   e. Lining: Inert and noncorrosive, propylene

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Hot-water heating piping, aboveground, NPS 3 and smaller, shall be any of the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
2. Schedule 40 steel pipe; Class 125, cast-iron fittings; cast-iron flanges and flange fittings; and threaded joints.

B. Hot-water heating piping, aboveground, NPS 4 and larger, shall be the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

C. Chilled-water piping, aboveground, NPS 2 and smaller, shall be any of the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
2. Schedule 40 steel pipe; Class 125, cast-iron fittings; cast-iron flanges and flange fittings; and threaded joints.

E. Chilled-water piping, aboveground, NPS 4 and larger, shall be the following:

1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

F. Chilled-water coil condensate drain piping, shall be the following:

1. Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered or press-fit joints.
2. PVC Schedule 40 with solvent-based fittings.
   a. Protect pipe with fire-rated insulation if installed in air plenum.

3.2 INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

H. Install fittings for changes in direction and branch connections.

I. Install piping to allow application of insulation.

J. Select system components with pressure rating equal to or greater than system operating pressure.

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using mechanically formed tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

P. Install valves according to Section 230523 "General-Duty Valves for HVAC Piping."

Q. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

S. Install shutoff valve immediately upstream of each dielectric fitting.

T. Paint (oil based) steel piping before installing.

3.3 DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

B. Dielectric Fittings for NPS 2 and Smaller: Use dielectric nipples [unions]

C. Dielectric Fittings for NPS 2-1/2 to NPS 4: Use dielectric flanges

D. Dielectric Fittings for NPS 5 and Larger: Use dielectric flange kits

3.4 HANGERS AND SUPPORTS

A. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hanger, support, and anchor devices. Comply with the following requirements for maximum spacing of supports.

B. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.
2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
4. Spring hangers to support vertical runs.
5. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
6. On plastic pipe, install pads or cushions on bearing surfaces to prevent hanger from scratching pipe.

C. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 7 feet
2. NPS 1: Maximum span, 7 feet
3. NPS 1-1/2: Maximum span, 9 feet
4. NPS 2: Maximum span, 10 feet
5. NPS 2-1/2: Maximum span, 11 feet
6. NPS 3 and Larger: Maximum span, 12 feet

D. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 5 feet; minimum rod size, 1/4 inch
2. NPS 1: Maximum span, 6 feet; minimum rod size, 1/4 inch
3. NPS 1-1/4: Maximum span, 7 feet; minimum rod size, 3/8 inch
4. NPS 1-1/2: Maximum span, 8 feet; minimum rod size, 3/8 inch
5. NPS 2: Maximum span, 8 feet; minimum rod size, 3/8 inch
6. NPS 2-1/2: Maximum span, 9 feet; minimum rod size, 3/8 inch
7. NPS 3 and Larger: Maximum span, 10 feet; minimum rod size, 3/8 inch

3.5 PIPE JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12, using qualified processes and welding operators according to "Quality Assurance" section.

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

H. Mechanically Formed, Copper-Tube-Outlet Joints: Use manufacturer recommended tool and procedure, and brazed joints.

I. Pressure-Sealed Joints: Use manufacturer-recommended tool and procedure. Leave insertion marks on pipe after assembly.

3.6 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install bypass piping with ball valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 230519 "Meters and Gages for HVAC Piping."

3.7 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 232113

SECTION 232923 – VARIABLE FREQUENCY DRIVES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes separately enclosed, preassembled, combination VFDs, rated 600 V and less, for speed control of three-phase, standard Type Design B induction motors.

1.3 DEFINITIONS

A. BAS: Building automation system.

B. CE: Conformite Europeene (European Compliance).

C. CPT: Control power transformer.

D. DDC: Direct digital control.

E. EMI: Electromagnetic interference.

F. LED: Light-emitting diode.

G. NC: Normally closed.

H. NO: Normally open.

I. OCPD: Overcurrent protective device.

J. PID: Control action, proportional plus integral plus derivative.

K. RFI: Radio-frequency interference.

L. VFD: Variable-frequency drive.

1.4 ACTION SUBMITTALS

A. Product Data: For each type and rating of VFD indicated.

1. Include dimensions and finishes for VFDs.

2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Shop Drawings: For each VFD indicated.

1. Include mounting 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, showing dimensioned layout on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Required working clearances and required area above and around VFDs.
2. Show VFD layout and relationships between electrical components and adjacent structural and mechanical elements.
3. Show support locations, type of support, and weight on each support.
4. Indicate field measurements.

B. Qualification Data: For testing agency.

C. Seismic Qualification Certificates: For each VFD, accessories, and components, from manufacturer.

1. Certificate of compliance.
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. Product Certificates: For each VFD from manufacturer.

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 VFDs to include emergency, operation, and maintenance manuals.

1. Include the following:
   a. For circuit breakers: Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and motor-circuit protector trip settings
   b. For field-adjustable overload relays: Manufacturer's written instructions for setting field-adjustable overload relays.
   c. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
   d. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.
   e. Load-Current and Overload-Relay Heater List: Compile after motors have been installed and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.
   f. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

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. Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
2. Control Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two of each size and type.
3. Indicating Lights: Two of each type and color installed.
4. Auxiliary Contacts: Furnish one spare for each size and type of magnetic controller installed.
5. Power Contacts: Furnish three spares for each size and type of magnetic contactor installed.

1.8 QUALITY ASSURANCE

A. Testing Agency Qualifications: Member company of NETA or an NRTL.

1. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
2. IEEE Compliance: Fabricate and test enclosed controllers according to IEEE 344 to withstand seismic forces defined in Section 26 05 48.16 "Seismic Controls for Electrical Systems."
3. Source Limitations: Obtain enclosed controllers of a single type through one source from a single manufacturer.
4. Comply with NFPA 70, “National Electrical Code.”
5. Comply with NECA 230, “Standard for Selecting, Installing, and Maintaining Electric Motors and Motor Controllers.”
6. Product Selection for Restricted Space: Drawings indicate maximum dimensions for enclosed controllers, minimum clearances between enclosed controllers, and for adjacent surfaces and other items. Comply with indicated maximum dimensions and clearances.

1.9 DELIVERY, STORAGE, AND HANDLING

A. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside.

1.10 WARRANTY

A. Special Warranty: Manufacturer agrees to repair or replace VFDs that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Allen Bradley
2. Mitsubishi Electric
3. Yaskawa Electric America, Inc.

2.2 SYSTEM DESCRIPTION

A. General Requirements for VFDs:

1. The VFDs shall be solid state, with 6-Pulse Width Modulation (PWM) output. The VFD package as specified herein shall be enclosed in a Type 1 enclosure, completely assembled, and tested by the manufacturer. The VFD shall employ a full wave rectifier, capacitors, and Insulated Gate Bipolar Transistors (IGBT's) as the output-switching device. The drive efficiency shall be 97% or better at full speed and full load. The displacement power factor shall be no less than 0.98 at all speeds and loads.
2. VFDs and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508A

B. Application: Variable torque

C. VFD Description: Variable-frequency motor controller, consisting of power converter that employs pulse-width-modulated inverter, factory built and tested in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

1. Units suitable for operation of NEMA MG 1, Design A and Design B motors, as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable- Voltage or Adjustable-Frequency Controls or Both."
2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

D. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

E. Output Rating: Three phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range; maximum voltage equals input voltage.

F. Unit Operating Requirements:

1. Input AC Voltage Tolerance: Plus 10 and minus 10 percent of VFD input voltage rating.
2. Input AC Voltage Unbalance: Not exceeding 3 percent.
3. Input Frequency Tolerance: Plus, or minus 3 percent of VFD frequency rating.
4. Minimum Efficiency: 97 percent at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: 98 percent under any load or speed condition.
6. Minimum Short-Circuit Current (Withstand) Rating: 22kA.
7. Vibration Withstand: Comply with NEMA ICS 61800-2.
8. Overload Capability: 1.1 times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
9. Starting Torque: Minimum 100 percent rated torque from 3 to 60 Hz.
10. Speed Regulation: Plus, or minus 5 percent.
11. Output Carrier Frequency: Selectable; 0.5 to 15 kHz.
12. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.

G. Inverter Logic: Microprocessor based, 16 bit, isolated from all power circuits.

H. Isolated Control Interface: Allows VFDs to follow remote-control signal over a minimum 40:1 speed range.

1. Signal: Electrical.

I. Internal Adjustability Capabilities:

1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: 0.1 to 999.9 seconds.
4. Deceleration: 0.1 to 999.9seconds.
5. Current Limit: 30 to minimum of 150 percent of maximum rating.

J. Self-Protection and Reliability Features: The VFD shall have the following protection circuits. The drive shall announce in full text the fault condition on the keypad display and shall display a HELP function which explains the possible cause of faults and the possible remedy. The following protection circuits are:

1. Surge Suppression: Factory installed as an integral part of the VFD, complying with UL 1449 SPD, Type 1 or Type 2.
2. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
3. Under- and overvoltage trips.
4. Inverter overcurrent trips.
5. VFD and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFDs and motor thermal characteristics, and for providing VFD over-temperature and motor-overload alarm and trip; settings selectable via the keypad.
6. Critical frequency rejection, with three selectable, adjustable dead bands.
7. Instantaneous line-to-line and line-to-ground overcurrent trips.
8. Loss-of-phase protection.
9. Reverse-phase protection.
10. Short-circuit protection including +24V.
11. Motor-overtemperature fault.
12. Each AC drive shall have single phase and over and under voltage protection of the drive and bypass system to ensure continued operation after utility power failures. Drive protection module shall be Allen Bradley 813S-V3-480V Ser B or pre-approved equal by CMS. Protection modules shall monitor incoming 480V-3 phase and shall interrupt the 120V control circuit. Modules shall be installed inside drive cabinets.
13. Ground fault protection.
14. Mains supervision.
15. Motor stall protection.
16. Motor underload protection

K. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Auto Speed Search" feature is available and engaged.

L. Bidirectional Auto speed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.

M. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

N. Speed Command Input shall be accomplished using any of the following:

1. Keypad.
2. Two analog inputs, each capable of accepting 0-20mA, 4-20mA, 0-10V, 2-10V signal, and direct NI 1000 temperature sensor input.
3. Serial Communications.

O. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

P. VFDs shall be capable of continuous full load operation under the following conditions:

1. Voltage tolerance + or - 10% of specified line voltage.
2. Output Frequency 0 to 150 Hz. Operation above 60 Hz shall require programming changes to prevent inadvertent high-speed operation.
3. Environmental operating conditions: 0 to 40°C, 0 to 1000 meters above sea level, less than 95% humidity, non-condensing.
4. Enclosure shall be rated UL Type enclosures or as specifically mentioned elsewhere.

Q. VFDs shall have the following standard features:

1. All VFDs shall have the same customer interface, including digital display and keypad, regardless of horsepower rating. The keypad is to be used for local control, for setting all parameters and for stepping through the displays and menus. The keypad shall be removable, capable of remote mounting and have its own non-volatile memory. The keypad shall be capable of uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.
2. The keypad shall include Hand, Auto, and Off selections. When in "Hand", the VFD will be started, and the speed will be controlled from the up/down arrows. When in "Off", the VFD will be stopped. When in "Auto", the VFD will start via an external contact closure and the VFD speed will be controlled via an external speed reference. The drive shall incorporate "bumpless transfer" of speed reference when switching between "Auto" and "Hand" modes.
3. All circuit boards shall be varnished to meet IEC 60068-2-60 Method 1 and be able to withstand hydrogen sulfide (H2S) and sulfur dioxide (SO2)
4. A built-in time clock shall be housed in the keypad. The clock shall have a battery backup with 10 years minimum life span, The clock shall be used to date and time stamp faults and record operating parameters at the time of fault.
5. The VFD shall have start-up wizards visible on the keypad for quick access to application macros specifically designed to facilitate start-up.
6. The user shall be able to define any parameter as a favorite using the keypad.
7. The VFD shall have cooling fans designed to be replaced without removing the VFD from the wall or removing the VFD enclosure. The cooling fan shall operate for a period of 10 years before it is replaced.
8. The VFD shall include capacitors which do not require conditioning prior to installation. The VFD shall have an infinite shelf life.

9. The VFD fans shall operate only when require. The user shall have the ability to choose additional cooling fan control.

10. The VFD shall monitor and display using the keypad nine (9) parameters at one time without the need to scroll through multiple screens. Each parameter shall be user defined. The following is a sample of the parameters which can be monitored and view using the keypad. All parameters viewed from the list below shall be capable of being displayed at all times. The display shall be in complete English words (alpha-numeric codes are not acceptable).

Output Frequency	Motor Current
Motor Speed (RPM, %, or Hz)	Calculated Motor Power (kW)
Calculated Motor Torque	Heatsink Temperature (deg F)
DC Bus Voltage	Analog Input Values
Output Voltage	Keypad Reference Values
Analog Output Value	KWh meter (resettable)
Elapsed Time Meter (resettable)	Digital input status
MWh meter	Digital output status

11. The VFD shall include a Quick Start-up wizard that leads the user through the typical HVAC required parameters.

12. The VFD shall have the ability to automatically restart after an overcurrent, overvoltage, undervoltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between reset attempts shall be programmable.

13. The VFD shall be capable of starting into a rotating load (forward or reverse) and accelerate or decelerate to setpoint without safety tripping or component damage (flying start).

14. The VFD shall also be capable of DC injection braking that can be employed to stop a freewheeling motor prior to starting to avoid overvoltage nuisance tripping.

15. The VFD shall have the ability to be programmed to automatically extend the ramp-down time as required to keep the drive from tripping on over-voltage caused by regeneration of power by the load.

16. If the input reference (0/4-20mA or 0/2-10V) is lost, the VFD shall give the user the option of either: (1) stopping and displaying a fault, (2) running at a programmable preset speed, (3) holding the VFD speed based on the last good reference received, or (4) causing a warning to be issued, as selected by the user. The drive shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communication bus.

17. The VFD shall include two-zone PID controllers that allow the drive to maintain PID control from two separate feedback signals. VFD shall include two PID set point sources, a sleep mode function, PID set point boost and a feed forward function to improve process response.

18. Run permissive circuit shall be included for damper or valve control.

19. The customer terminal strip shall be isolated from the line and ground.

20. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute in every 10 minutes.

21. The VFD shall have integrated harmonic filters equivalent to 5% impedance line reactors.

22. The VFD shall incorporate a Multi-Pump Controller Wizard capable of controlling up to five motors. The VFD is connected to one motor which is the "regulating" motor connecting and disconnecting the other motors to/from the mains, by means of contactors controlled with relays to maintain a given set point. This function shall have an auto-change function for changing starting order of pumps which allows for equal wear on all pumps.

23. The VFD shall be capable of sensing a loss of load (broken belt / no water in pump) or high current mechanical sensing failure and signal the loss of load condition. The drive shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus.

24. The VFD shall include a motor switch ride through and is enabled or disabled through the keypad. This feature allows the motor maintenance switch to be opened and closed without stopping or tripping the drive.

R. All VFDs to have the following adjustments:

1. Three (3) programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed.

2. A custom PID preset for HVAC and fluid systems, allowing a pressure or flow signal to be connected to the VFD, using the microprocessor in the VFD for the closed loop control. A sleep mode shall be included in the PID functions. This feature shall allow the motor to be stopped when at minimum speed for a user defined period, for additional energy savings.

3. Two (2) programmable analog inputs shall accept a current or voltage.

4. Analog inputs shall include a filter to remove any oscillation in the input signal. The minimum and maximum values (gain and offset) shall be adjustable within the range of 0-20 mA and 0-10 Volts. Additionally, the reference must be able to be scaled so that maximum reference can represent a frequency less than 60 Hz, without lowering the drive maximum frequency below 60 Hz. Process variables shall be capable of being inverted.

5. Six (6) programmable digital inputs for maximum flexibility in interfacing with external devices. These inputs can also be used to activate the setpoints of individual control loops.

6. One (1) programmable analog output proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, Active Reference, and other data.

7. Two (2) programmable digital relay outputs. The relays shall be rated for maximum switching current 8 amps at 250 Vac and 0.4A at 125 Vac. Outputs shall be full form C relay contacts; open collector outputs are not acceptable.

8. The VFD shall be capable of adding additional I/O as required for the system. The additional I/O shall mount in the drive and not require bypass configuration. Additional I/O include:

   a) Six (6) additional programmable digital inputs or outputs

   b) Five (5) digital inputs with a relay output

   c) 2 additional relay outputs with a thermostat

   d) One (1) each additional Analog Input and two (2) analog outputs

   e) Three (3) relay outputs

9. Fifteen (15) programmable preset speeds.

10. Two independently adjustable accel and decel ramps. These ramp times shall be adjustable from 1 to 3600 seconds.

11. The VFD shall be capable of catching a "spinning motor" as programmed by the user.

12. The VFD shall Ramp or Coast to a stop, as selected by the user.

13. The displayed operating information shall be user selectable and include up to nine parameters which can be viewed and monitored at one time.
14. All applicable operating values shall be displayed in engineering (user) units.
15. The keypad shall include a backlit LCD display. The display shall be in complete words for programming and fault diagnostics.
16. The keypad shall utilize wizards to help navigate your HVAC application. These wizards will walk you through the steps required for PID set-up, Start-up and Multi-pump applications.
17. The VFDs shall include a fireman's override input.
18. All VFDs shall include EMI/RFI filters. The filters shall allow the VFD assembly to be CE marked and meet product standard EN 61800-3 for the First Environment restricted level (Category C2).
19. The VFD shall have an optional integrated disconnect switch which will not add any additional enclosures to the drive and be the same footprint as a drive without an integral disconnect switch.
20. The VFD shall have the following protection circuits. The drive shall announce in full text the fault condition on the keypad display and shall display a HELP function which explains the possible cause of the fault and the possible remedy. The following protection circuits are:
    a) Overcurrent
    b) Overvoltage
    c) Undervoltage
    d) Unit over-temperature protection
    e) Ground fault protection
    f) Mains supervision
    g) Motor phase supervision
    h) Motor stall protection
    i) Motor overload protection
    j) Motor underload protection
    k) Short-circuit protection of +24V
21. Speed Command Input shall be accomplished using any of the following:
    a) Keypad
    b) Two Analog inputs, each capable of accepting a 0-20mA, 4-20mA, 0-10V, 2-10V signal, and direct NI 1000 temperature sensor input.
    c) Serial Communications

S. Integral Input Disconnecting Means and OCPD: UL 489, thermal-magnetic circuit breaker with pad-lockable, door-mounted handle mechanism.
   a. Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFD input current rating, whichever is larger.
   b. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
   c. NC alarm contact that operates only when circuit breaker has tripped.

2.3 PERFORMANCE REQUIREMENTS (NOT USED)

2.4 CONTROLS AND INDICATION

A. Status Lights: Door-mounted LED indicators displaying the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.

B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English-language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.

1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
2. 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.
    a. Control Authority: Supports at least four conditions: Off, local manual control at VFD, local automatic control at VFD, and automatic control through a remote source.

C. Historical Logging Information and Displays:

1. Real-time clock with current time and date.
2. Running log of total power versus time.
3. Total run time.
4. Fault log, maintaining last [four] faults with time and date stamp for each.

D. Indicating Devices: Digital display and additional readout devices as required, mounted flush in VFD door and connected to display VFD parameters including, but not limited to:

1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (V dc).
9. Set point frequency (Hz).
10. Motor output voltage (V ac).

E. Control Signal Interfaces:

1. Electric Input Signal Interface:

a. A minimum of six multifunction programmable digital inputs.

2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the DDC system for HVAC or other control systems:

a. 0- to 10-V dc.

b. 4- to 20-mA dc.

c. Potentiometer using up/down digital inputs.

d. Fixed frequencies using digital inputs.

3. Output Signal Interface: A minimum of one programmable analog output signal ([0- to 10-V dc] [4- to 20-mA dc] [operator-selectable "x"- to "y"-mA dc]), which can be configured for any of the following:

a. Output frequency (Hz).

b. Output current (load).

c. DC-link voltage (V dc).

d. Motor torque (percent).

e. Motor speed (rpm).

f. Set point frequency (Hz).

4. Remote Indication Interface: A minimum of two programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

a. Motor running.

b. Set point speed reached.

c. Fault and warning indication (overtemperature or overcurrent).

d. PID high- or low-speed limits reached.

F. Interface with DDC System for HVAC: Factory-installed hardware and software shall interface with DDC system for HVAC to monitor, control, display, and record data for use in processing reports. VFD settings shall be retained within VFD's nonvolatile memory.

1. Hardwired Points:

a. Monitoring: Run Status (binary output)

b. Control: Start/Stop (binary input)

c. Speed Command (analog input)

d. Fault (binary output)

e. Fault Reset (binary input)

2. Communication Interface: Comply with ASHRAE 135. Communication with the BAS to remotely control and monitor VFD will be performed over BACnet IP.

2.5 LINE CONDITIONING AND FILTERING (NOT USED)

2.6 BYPASS SYSTEMS

A. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely

disconnected from power converter.

B. Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic-control system feedback.

C. Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller; with input isolating switch and barrier arranged to isolate the power converter input and output and permit safe testing and troubleshooting of the power converter, both energized and de- energized, while motor is operating in bypass mode.

1. Bypass Contactor: Load-break, NEMA-rated contactor.
2. Input and Output Isolating Contactors: Non-load-break, NEMA-rated contactors.
3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

D. Bypass Contactor Configuration: Full-voltage (across-the-line) type.

1. NORMAL/BYPASS selector switch.
2. HAND/OFF/AUTO selector switch.
3. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFD while the motor is running in the bypass mode.
4. Contactor Coils: Pressure-encapsulated type with coil transient suppressors.
    a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
    b. Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
5. Control Circuits: 24-V ac; obtained from integral CPT, with primary and secondary fuses. Source of Control Power will be determined by the contractor based on existing conditions, with CPT of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.
    a. CPT Spare Capacity: 100 VA.
6. Overload Relays: NEMA ICS 2.
    a. Bimetallic Overload Relays:
        1) Inverse-time-current characteristic.
        2) Class 20 tripping characteristic.
        3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
        4) NO isolated overload alarm contact.
        5) External overload, reset push button.

2.7 OPTIONAL FEATURES (NOT USED)

2.8 ENCLOSURES

A. VFD Enclosures: NEMA 250, to comply with environmental conditions at installed location.

1. Dry and Clean Indoor Locations: Type 1.

2.9 ACCESSORIES

A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFD enclosure cover unless otherwise indicated.

1. Push Buttons: Unguarded.
2. Pilot Lights: Push to test.
3. Selector Switches: Rotary type.
4. 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.

B. Reversible NC/NO bypass contactor auxiliary contact(s).

C. Control Relays: Auxiliary and adjustable solid-state time-delay relays.

D. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.

1. Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.

E. Supplemental Digital Meters:

1. Elapsed-time meter.
2. Kilowatt meter.
3. Kilowatt-hour meter.

F. Spare control-wiring terminal blocks; wired.

2.10 SOURCE QUALITY CONTROL

A. Testing: Test and inspect VFDs according to requirements in NEMA ICS 61800-2.

1. Test each VFD while connected to its specified motor.
2. Verification of Performance: Rate VFDs according to operation of functions and features specified.

B. VFDs 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 areas, surfaces, and substrates to receive VFDs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance of the Work.

B. Examine VFD before installation. Reject VFDs that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before

VFD installation.

D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

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

3.2 INSTALLATION

A. Wall-Mounting Controllers: Install with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished floor, unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall.

B. Install fuses in each fusible-switch VFD.

C. Install fuses in control circuits if not factory installed.

D. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors are installed.

E. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.

F. Comply with NECA 1.

3.3 CONTROL & POWER WIRING INSTALLATION

A. Install wiring between VFDs and remote devices.

B. Bundle, train, and support wiring in enclosures.

C. Connect selector switches and other automatic-control devices where applicable.

1. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switches are in manual-control position.
2. Connect selector switches with control circuit in both manual and automatic positions for safety- type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor- overload protectors.

D. Install VFD rated wiring for power from the VFD to its associated motor per VFD Manufacturer.

3.4 IDENTIFICATION

A. Identify VFDs, components, and control wiring, per CMS wiring standards.

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each VFD with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.

B. Operating Instructions: Frame printed operating instructions for VFDs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFD units.

3.5 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. Acceptance Testing Preparation:

1. Test insulation resistance for each VFD element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

E. Tests and Inspections:

1. Inspect VFD, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Test insulation resistance for each VFD element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at VFD locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify Architect before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform tests according to the Inspection and Test Procedures for Adjustable Speed Drives stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
    a. Perform the following infrared (thermographic) scan tests and inspections and prepare reports: Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFD. Remove front panels so joints and connections are accessible to portable scanner.
    b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFD 11 months after date of Substantial Completion.
    c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
8. Test and adjust controls, remote monitoring, and safety. Replace damaged and malfunctioning controls and equipment.

F. VFDs will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports, including a certified report that identifies the VFD and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.6 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.

3.7 ADJUSTING

A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to

Substantial Completion.

B. Set the taps on reduced-voltage autotransformer controllers.

C. Set field-adjustable circuit-breaker trip ranges as per VFD Manufacturer’s requirements.

3.8 PROTECTION

A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.

B. Replace VFDs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.9 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, reprogram, and maintain VFDs.

END OF 232923

SECTION 234320 – AIR PURIFICATION SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

A. This section describes the design, performance, and installation of an air purification system intended for use as part of another manufacturer's air handling unit.

1.2 REFERENCED CODES AND STANDARDS

A. The following codes and standards are referenced throughout. The edition to be used is that currently enforced by the authority having jurisdiction (AHJ) or, in absence of such direction, that referenced by the current enforceable IBC code or as indicated by the contract documents, except where specifically referenced by this section of the specifications.

1. ASHRAE Standard 52-2017 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

2. ASHRAE Standard 62-2016 Ventilation for Acceptable Indoor Air Quality.

3. National Electric Code NFPA 70

4. UL 867-2007 including ozone chamber test required as of December 21, 2007

5. UL 2998 Environment – Zero Ozone Emission. Products without UL 2998 will not be acceptable.

6. The cold plasma equipment and power supply shall be UL listed.

1.3 RELATED WORK

A. Facility Access and Protection

B. Ductwork

C. Filters

D. Water and Refrigerant Piping

E. Electrical Wiring

F. Control Wiring

1.4 QUALITY AND IP ASSURANCE

A. Basis of design is Global Plasma Solutions GPS FC-48. Approved equals by Airgenics and Bioxgen subject to specification.

B. The Air Purification System shall be a product of an established manufacturer within the USA. Direct Current (DC) Ion modules manufactured outside the USA and assembled in the USA on mounting plates or formed channels shall not be acceptable.

C. A qualified representative from the manufacturer shall be available to inspect the installation of the air purification system to ensure installation in accordance with manufacturer's recommendation.

D. Technologies that do not address gas disassociation such as UV Lights, Powered Particulate Filters and/or polarized media filters shall not be considered. Uni-polar ion generators shall not be acceptable. “Plasma” particulate filters shall not be acceptable. Any system containing titanium dioxide (Ti02), which has been

listed by the CDC as a known carcinogen, shall not be acceptable.

E. The Air Purification Technology shall have been tested by UL to prove conformance to UL 867-2007 including the ozone chamber testing and peak ozone test for electronic devices. Manufacturers that achieved UL 867 prior to December 21, 2007 and have not been tested in accordance with the newest UL 867 standard with the ozone amendment, shall not be acceptable. All manufacturers requesting prior approval shall submit their independent UL 867 test data with ozone results to the engineer for preliminary review and during the submittal process. All manufacturers shall submit a copy with their quotation. Contractors shall not accept any proposal without the proper ozone testing documentation.

F. The maximum allowable ozone concentration per the UL 2998 chamber test shall be 5 PPB. Manufacturers with ozone output exceeding these ozone values shall not be acceptable.

G. All manufacturers shall have their product tested to UL 2998 Environmental Standard for confirmation of no ozone with certificate available. The final report shall indicate the ozone levels and high voltage output the device's electrode(s) were operating at during the test. Reports that do not include high voltage output during the UL 2998 testing shall not be acceptable.

1.5 SUBMITTALS

A. Product Data: Submit manufacturer's technical product data for ion generators, including:

1. Schedule of plasma generators indicating unit designation, number of each type required for each unit/application.

2. Data sheet for each type of plasma generator, and accessory furnished, indicating construction, sizes, and mounting details.

3. Performance data for each type of plasma device furnished.

4. Product drawings detailing all physical, electrical and control requirements.

5. Copy of UL 867 independent ozone test.

6. Copy of UL 2998 conformance certificate.

7. Statement on the manufacturer's letterhead stating that the technology contains no titanium dioxide (Ti02).

B. Operating and Maintenance (O&M) Data: Submit O&M data and recommended spare parts lists.

1.6 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver in factory fabricated shipping containers. Identify on outside of container type of product and location to be installed. Avoid crushing or bending.

B. Store in original cartons and protect from weather and construction work traffic.

C. Store indoors and in accordance with the manufacturers' recommendation for storage.

1.7 WARRANTY

A. Equipment shall be warranted by the manufacturer against defects in material and workmanship for a period of eighteen months after shipment or twelve months from owner acceptance, whichever occurs first. Labor to replace equipment under warranty shall be provided by the installing contractor.

PART 2 - PRODUCTS

2.1 GENERAL

A. The air purification system(s) shall be of the size, type, arrangement, and capacity indicated and required by the unit furnished and shall be of the manufacturer specified.

2.2 BI-POLAR IONIZATION DESIGN AND PERFORMANCE CRITERIA

A. Each piece of air handling equipment, so designated on the plans, details, equipment schedules and/or specifications shall contain a Plasma Generator with Bi-polar Ionization output as described here within.

B. The Bi-Polar Ionization system shall be capable of:

1. Effectively killing microorganisms downstream of the bi-polar ionization equipment (mold, bacteria, virus, etc.)

2. Controlling gas phase contaminants generated from human occupants, building structure, furnishings, and outside air contaminants.

3. Be self-cleaning, requiring minimal maintenance. Units that are not self-cleaning will not be acceptable.

4. Capable of reducing static space charges.

5. Effectively reducing space particle counts.

6. When mounted to the air entering side of a cooling coil, keep the cooling coil free from pathogen and mold growth.

7. All manufacturers shall provide documentation by an independent NELEC accredited laboratory that proves the product has minimum kill rates for the following pathogens given the allotted time and in a space condition:
   a. MRSA - >96% in 30 minutes or less
   b. E.coli - > 99% in 15 minutes or less
   c. TB - > 69% in 60 minutes or less
   d. C. diff - >86% in 30 minutes or less
   e. Noro Virus -> 93.5% in 30 minutes or less
   f. Legionella -> 99.7% in 30 minutes or less
   g. SARS-2-COV: Manufacturer to supply efficacy data

   Manufacturers not providing the equivalent space kill rates shall not be acceptable. All manufactures requesting prior approval shall provide to the engineer independent test data from a NELAP accredited independent lab confirming kill rates and time meeting the minimum requirements stated in section 2.2 B, points 6A, 6B, and 6C. Products tested only on Petri dishes to prove kill rates shall not be acceptable. Products being sold under different trade names than those tested shall not be acceptable.

8. Capable of modular field assembly in six-inch (150mm) sections.

C. The bi-polar ionization system shall operate in a manner such that equal amounts of positive and negative ions are produced. Uni-polar ion devices shall not be acceptable. Ionizers with positive and negative output (DC type) shall not be acceptable. All ionizers provided shall be AC type ionizers with one electrode pulsing between positive and negative.

1. Air exchange rates may vary through the full operating range of a constant volume or VAV system. The quantity of air exchange shall not be increased due to requirements of the air purification system.

2. Velocity Profile: The air purification device shall not have maximum velocity profile.

D. Humidity: Plasma Generators shall not require preheat protection when the relative humidity of the entering air exceeds 85% RH. Relative humidity from 0-100% RH condensing shall not cause damage, deterioration, or dangerous conditions within the air purification system. Air purification system shall be capable of wash down duty.

E. Equipment Requirements:

1. Electrode Specifications (Bi-polar Ionization):
   a. Each alternating current (AC) Ionization Bar with Bi-polar Ionization output shall include a minimum of eighteen carbon fiber cluster ion needles per foot of coil face width. The entire cooling coil width shall have equal distribution of ionization across the face. Systems without ion needles at least 0.50" (12.5mm) apart shall not be acceptable. The plasma electrode shall require no more than 1.0" (25mm) in the direction of airflow for mounting. All hardware required for mounting shall be provided by the air purification manufacturer except self-tapping screws for the power supply. Bi-polar ionization tubes manufactured of glass and steel mesh shall not be acceptable due to replacement requirements, maintenance, and performance output reduction over time, ozone production and corrosion.
   b. Electrodes shall be provided in 6.0" (150mm) increments, epoxy filled for an IP55 rating and utilizing brass connection hardware that is recessed into the connection joint once fully engaged and assembled.
   c. Electrodes shall be energized when the main unit disconnect is turned on.
   d. The ionization output shall be a minimum of 60 million ions/cc per inch of cooling coil width as measured 1.0" from the cold plasma needles.
   e. Ionization bars shall be provided with magnet mounting kits to prevent penetration into cooling coils.
   f. Ionization bars shall be constructed of UL 94VO and UL746C composite material.

F. Air Handler Mounted Units:

1. Where so indicated on the plans and/or schedules Plasma Generator(s) shall be supplied and installed. The Mechanical Contractor shall mount the Plasma Generator and wire it to the remote mount power supply using the cables provided by the air purification manufacturer. A 24VAC, 115VAC or 208-230VAC circuit shall be provided to the plasma generator power supply panel. No more than 15 watts shall be required per power supply. Each power supply shall be capable of powering up to 6 ionization bars or a total of 50 linear feet of bar(s). Each plasma generator shall be designed with fiberglass housing, liquid tight flexible conduit, and a high voltage quick connector.

G. Plasma Requirements:

1. Plasma Generators with Bi-polar ionization output shall be capable of controlling gas phase contaminants and shall be provided for all equipment listed above.
   a. The Bi-polar Ionization system shall consist of Bi-Polar Plasma Generator and power supply. The Bi-polar system shall be installed where indicated on the plans or specified to be installed. The device shall be capable of being powered by 24VAC, 115VAC, or 208-230VAC without the use of an external transformer. Ionization systems requiring isolation transformers shall not be acceptable.
   b. Ionization Output: The ionization output shall be controlled such that an equal number of positive and negative ions are produced (AC Ionizers only are acceptable). Imbalanced levels shall not be acceptable.
   c. Ionization output from each bar shall be a minimum of 120 million ions/cc per inch of bar when tested at 1" from the ionization bar. Bars with needles spaced further apart than 0.5" shall not be acceptable.
   d. Each plasma electrode shall be made from an all-fiberglass composite, UL 94V0 and UL 746C rated material for prevention of corrosion and electrical insulation.

2. Ozone Generation:
   a. The operation of the electrodes or Bi-polar ionization units shall conform to UL 2998 as tested by UL proving no ozone output.

H. Electrical Requirements:

1. Wiring, conduit, and junction boxes shall be installed within housing plenums in accordance with NEC NFPA 70. Plasma Generator shall accept an electrical service of 24VAC, 115 VAC, or 208-230VAC, 1 phase, 50/60 Hz. The Contractor shall coordinate electrical requirements with air purification manufacturer during submittals.

I. Control Requirements:

1. All Plasma Generators shall have internal short circuit protection, overload protection, and automatic fault reset. Systems requiring fuses shall not be acceptable.

2. The Plasma Generator power supply shall have internal circuitry to sense the ionization output and provide dry contact alarm status to the BMS as well as a local “Plasma On” indication light.

3. The installing contractor shall mount and wire the Plasma device within the air handling unit specified or as shown or the plans. The contractor shall follow all manufacturer IOM instructions during installation.

PART 3 - EXECUTION

3.1 GENERAL

A. The Mechanical Contractor shall be responsible for maintaining all air systems until owner accepts the building (Owner Acceptance.)

3.2 ASSEMBLY AND ERECTION: PLASMA GENERATOR

A. All equipment shall be assembled and installed in a workman like manner to the satisfaction of the owner and engineer.

B. Any material damaged by handling, water or moisture shall be replaced, by the Mechanical Contractor, at no cost to the owner.

C. All equipment shall be protected from dust and damage daily throughout construction.

3.3 TESTING

A. Provide the manufacturer’s recommended electrical tests.

3.4 COMMISSIONING AND TRAINING

A. A manufacturer’s authorized representative shall provide start-up supervision and training of owner’s personnel in the proper operation and maintenance of all equipment.

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