TECHNICAL SPECIFICATIONS FOR MECHANICAL WORKS

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I. GENERAL PROVISIONS FOR MECHANICAL WORKS

PART 1 - GENERAL

1.1 GENERAL

A. In case of conflict between these General Provisions and the Special and General Conditions the more restrictive requirements will generally govern but this should be brought to the Consultants attention.

B. The drawings are schematic and diagrammatic and are intended to be a graphic representation of the contract requirements. Due to restrictions of scale, complete details cannot be shown. It is however, assumed to represent a complete installation. The contractor shall be responsible for providing a complete installation, coordination with other trades, and coordination with field conditions.

C. Riser diagrams and schematic diagrams generally indicate equipment connections to be used for various systems. Provide all work shown on diagrams whether or not it is duplicated on the plans.

D. Specifications include incomplete sentences. Words or phrases such as “the contractor shall,” “shall be,” “furnish,” “provide,” “a,” “an,” “the,” and “all” have been omitted for brevity.

E. Except where modified by a specific notation to the contrary, the indication and/or description of any item, in the Drawings or Specifications or both, carries with it the instruction to furnish and install the item complete with all appurtenances or accessories necessary to complete any required system, regardless of whether or not this instruction is explicitly stated as part of the indication or description.

F. Specifications and Drawings are complimentary and are to be taken together for a complete interpretation of the work. Where conflicts exist between the drawings and specifications, the item (s) of greater quantity or cost shall be provided for in the contract price. The item shall be brought to the attention of the Consultant.

G. Drawings of necessity utilize symbols and schematic diagrams to indicate various items or work. Neither of these have any dimensions significance nor do they delineate every item required for the intended installation. Install the work in accordance with the diagrammatic intent expressed on the electrical and mechanical drawings, and in conformity with the dimensions indicated on final architectural and structural working drawings and on equipment shop drawings.

H. Certain details appear on the drawings, which are specific with regard to the dimensioning and positioning of the work. These details are intended only for the purpose of establishing general feasibility. They do not obviate field coordination for the indicated work.

I. Derive information as to the general construction from structural and architectural drawings and specifications.

J. Responsibility of contractor is to ensure that all works are in conformity with drawings, international stated codes and local regulations.

1.2 QUALITY ASSURANCE AND STANDARDS

A. Make the complete installation in accordance with all state and local municipal codes, all applicable codes and authorities having jurisdiction, and the applicable requirements and standards of the following:

1. BS-EN - British Standards / European Standards
2. ASA - American Standards Association
3. IEEE - Institute of Electrical and Electronics Engineers

4. ANSI - American National Standards Institute
5. ASHRAE - American Society of Heating, Refrigerating and Air Conditioning Engineers
6. ASME - American Society of Mechanical Engineers
7. ASTM - American Society for Testing and Materials
8. AWS - American Welding Society
9. AWWA - American Water works Society
10. AMCA - Air Movement and Control Association
11. MSS - Manufacturer's Standardization Society of the Valve and Fittings Industry
12. NEC - National Electrical Code
13. NEMA - National Electrical Manufacturers Association
14. PDI - Plumbing and Drainage Institute
15. SBI - Steel Boiler Institute
16. UL - Underwriters Laboratories
17. SMACNA - Sheet Metal and Air Conditioning Contractors National Association
18. NFPA - National Fire Protection Association

B. Provide all work necessary to comply with these requirements at no extra cost to the Employer.

1.3 ORGANISATION OF THE WORK

A. Put work in place as fast as possible to meet all construction schedules.

B. Keep a competent Engineer/ Superintendent in charge of the work. Replace such Engineer / Superintendent if unsatisfactory to the Project Manager.

C. Provide every facility to permit inspection or observation of the work by the Consultant during the course of construction.

D. Be responsible for work until its completion and final acceptance, replace any of the same which may be damaged, lost or stolen, without additional cost to the Employer.

1.4 ACCEPTANCE OF THE WORK

A. Make all workmanship, equipment and materials supplied under these specifications acceptable to the Consultant who has the power to reject any items which in its judgment are not in full accordance with the Drawings and Specifications.

1.5 SCOPE OF WORK

A. The specifications and the accompanying drawings are intended to secure the provisions of all material, labour, equipment, and services necessary to install complete, tested, re ady for operation and set to work the MEP in accordance with the Specifications and Drawings. Provide all systems complete with necessary appurtenances and minor auxiliaries, including offsets to clear interferences and supports, which are not shown but are needed to make each system complete in every respect. Provide all work described in the Specifications and not shown on the Drawings, or vice versa, in complete working order.

1.6 EXAMINATION OF EXISTING CONDITIONS

A. Before submitting a proposal, the contractor is responsible for visiting the site of the work and becoming thoroughly familiar with all conditions and limitations. The submission of a proposal will be construed as evidence that such an examination has been made, and later claims for labour, equipment or materials required for difficulties encountered which could have been foreseen had such an examination been made will not be recognized.

B. Verify all grades, elevations, dimensions and clearances at the site.

C. Verify existing conditions and bring any discrepancies to the Consultant's attention in writing prior to proposal submission.

1.7 SHOP DRAWINGS AND OTHER INFORMATION REQUIRED

A. Prior to purchasing equipment or materials, submit a list of proposed manufacturers to the Consultants for approval.

B. Shop drawings must comply with projects General Requirements and bear the Contractor's stamp certifying:

1. That the submitted shop drawings have been checked.
2. That the submitted shop drawings are fully coordinated with all interfacing trades and with other trades where interferences may occur.
3. That the submitted shop drawings are in conformance with the contract documents, except for noted substitutions and / or changes.

C. Prior to assembling or installing the work, submit the following for review:

1. Catalog information and factory assembly drawings, as required for a complete explanation and description of all items of equipment / piping.
2. Field installation drawings, as required to explain fully all procedures involved in erecting, mounting and connecting all items of equipment.
3. Scale drawings indicating insert and sleeve locations.
4. Scale composite drawings, showing all duct work, piping, lighting fixtures, main conduit runs and drainage piping above the hung ceilings and in the mechanical equipment rooms in relation with other trades (architectural and structural etc.) The drawings will indicate pipe and duct sizes and their elevation above the floor. Obtain layout of fire protection, HVAC and electrical work from the respective contractor for inclusion on the composite drawing. The signature of each contractor on the composite drawing will attest to full coordination of these drawings.

D. Coordinated Builders work drawings

E. Materials installed or work performed without acceptance of materials is done at the risk of the Contractor, and the cost of removal of such material or work, which is judged unsatisfactory for any reason, is at the expense of the Contractor plus cost of any other work affected.

F. Shop Drawings and other submissions, which are submitted for review, will be returned with a Shop Drawing stamp indicating actions based on reviews that are made and Contractor's responses that may be necessary.

G. All material submission shall be provided with a clause-by-clause specification compliance statement indicating all specified requirements are met.

1.8 RECORD DRAWINGS

A. Before commencing work, procure complete set of black and white prints of Contract Drawings.

B. Maintain prints in field office and permanently record, in coloured pencil, on such prints, at time of occurrences, deviations from Contract Drawings, due to:

1. Field Coordination
2. Addenda
3. Bulletins

C. Dimension underground utilities from permanent identifiable structural points.

D. Make drawings available for the Consultants periodic inspection and submit for review with As-Built drawings.

1.9 COORDINATION OF WORK WITH OTHER TRADES

A. Scaled and figured dimensions with respect to the items are approximate only sizes of equipment have been taken from typical equipment items of the class indicated. Before proceeding with work, carefully check all dimensions and sizes and assume full responsibility for the fitting-in of equipment and materials to the building and to meet architectural and structural conditions.

B. Refer to the Architectural Drawings for ceiling heights, locations and types of hung ceilings and furred spaces.

1.10 DELIVERY AND RECEIVING

A. Employer furnished equipment will be delivered, crated or otherwise packaged to the site delivery point selected by the Project Manager. The Contractor is responsible for accepting delivery of all Employer furnished items, which are under his trade jurisdiction and place them in their final location.

B. Where items cannot be immediately placed in their final position, the Contractor is responsible for storing and protecting all Employer furnished items until the time of their final installation. The contractor is responsible for the care and protection of the items until acceptance by the Employer.

1.11 PROTECTION AND PRODUCT HANDLING OF MECHANICAL AND ELECTRICAL EQUIPMENT

A. Deliver and store Mechanical and Electrical equipment at the site, properly packed and crated until finally installed. Investigate each space through which equipment must be moved. If necessary, have equipment shipped from manufacturer in crated sections of size suitable for moving through restricted spaces.

B. Adequately protect uninstalled and installed equipment and materials against loss or stealing, damage caused by water, paint, fire, plaster moisture, acids, fumes, dust to other environmental conditions, or physical damage, during delivery, storage, installation and shutdown conditions. Replace any damaged or stolen material without extra cost to the Employer.

C. Provide effective protection for all material and equipment against damage that may be caused by environmental conditions.

D. Provide effective protection against damage for all materials and equipment during shipment, and storage at the proper site. Cover all stored equipment to exclude dust and moisture. Place stored equipment on pallets or racks with appropriate weather cover.

E. Protect all rough and finished floors and other finished surfaces from damage, which may be caused by construction materials and methods. Protect floor with tarpaulins, chip pans and oil-proof floor covering. Protect finished surfaces form welding and cutting splatters with baffles and splatter blankets. Protect finished surfaces from paint droppings, adhesive and other marring agents with drop cloths. Protect other surfaces with appropriate protective measures.

F. Deliver materials to site in manufacturer’s original unopened containers with manufacturers name and product identification clearly marked thereon.

1.12 EQUIPMENT AND MATERIALS

A. Provide equipment and materials required for installation under the specifications new and without blemish or defect. Provide equipment and materials, which will meet the acceptance of authorities having jurisdiction over the work. Where such acceptance is contingent upon having the products listed or labeled by underwriters Laboratories inc. or other test laboratory, provide products so listed or labeled. Where no specific indication as to the type or quality of material or equipment is indicated, furnish a first-class standard article.

B. Wherever a manufacturer of a product is specified and the terms “other approved” or “approved equal” or “equal” or “similar to” are used, the substituted item must conform in all respects to the specified item, and meet the Consultants approval. Consideration will not be given to claims that the substituted item meets the performance requirements with lesser minimum performance. In many cases, equipment is oversized to allow for pick-up loads, de-rating and future loads which cannot be delineated under this minimum performance.

C. Substituted equipment were permitted and accepted must conform to space requirements. Replace at Contractor’s expense any substituted equipment that cannot meet space requirements, whether accepted or not. Make any modifications of related systems as a result of substitutions at Contractor’s expense.

D. Note that shop drawings, or other information submitted in accordance with the requirements hereinbefore specified, do not assure that the Consultant attests to the dimensional suitability of the material or equipment involved. Consultants’ approval of shop drawings for substituted equipment, does not waive the Contractor’s responsibility to assure proper fit with adequate clearances for maintenance.

E. Substitutions of equipment for that listed on the schedules or designated by model number in the specifications will not be considered if the proposed substitution is not a regular cataloged item shown in the current catalog of the manufacturer and has not been successfully used for a period of not less than five years or more.

1.13 COMMISSIONING AND PERFORMANCE TESTING

A. The commissioning and performance testing shall be carried out by an independent specialized firm. Full details of the capability and experience of such firm shall be submitted to the Consultant for review and approval.

1.14 OPERATING AND MAINTENANCE INSTRUCTIONS

A. After completion of all required equipment and system tests and unless specifically noted elsewhere in these specifications, provide at Employers convenience, knowledgeable personnel and necessary equipment to instruct and demonstrate the operation and maintenance of said equipment and systems. Arrange for the related manufacturer or authorized representative to assist with this orientation. The Orientation shall be a minimum of five days in addition to start of time.

B. Before requesting acceptance of work, furnish five (5) copies in bound form of a complete operation and maintenance manual printed.

1.15 GUARANTEES AND CETIFICATIONS

A. Guarantee all work to be free from leaks and defects. Replace or repair, as directed by the Consultant, defective materials or workmanship, as well as damage to the work of the Trades resulting form same for the duration of stipulated guarantee periods.

B. Submit certification attesting to the fact that specified performance and other criteria are met by all items of equipment.

1.16 SITE VISITS FOR OBSERVATION

A. As the project progresses, the Consultant, at his discretion, will perform site visits to observe the mechanical and electrical installations. At the conclusion of these site visits, punch lists or non-compliance notices will be issued to the appropriate Contractor for the deficiencies in the work of his trade. Complete all work and perform all corrective measures as required by the punch lists. After this corrective and completion work has been accomplished advise the Consultant in writing that every item on the punch lists has been completed.

1.17 PAINTING

A. Deliver all equipment with standard factory finish or as specified. Clean all equipment before acceptance by the Employer.

B. Except as otherwise specified, priming will be done under other sections of the work.

C. Any material transported in a piping system will be color-coded. Positive identification of contents of a piping system shall be by lettered legend giving the name of the material in full or abbreviated form. Arrows will be used to indicate the direction of flow. Color-coding shall be applied to the entire exposed piping system. Identifying color of materials one word in piping

Material		Color
1.	Blow-off water	Yellow
2.	Fire protection water	Red
3.	Fuel gas	Yellow
4.	Hot Water	Yellow
5.	Sanitary, water	Green
6.	Sprinkler, water	Red
7.	Storm sewer	Green
8.	Make-up water	Green
9.	Waste water	Green
10.	Water	Green

II. COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENTS

PART 2 - GENERAL

2.1 RELATED DOCUMENTS

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

2.2 SUMMARY

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

2.3 COORDINATION

A. Refer to other Division 23 Sections to determine if control coordination is required.

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

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

2.4 SUBMITTALS

A. Refer to other Division 23 Sections to determine if control coordination is required.

B. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

PART 3 - PRODUCTS

3.1 GENERAL MOTOR REQUIREMENTS

A. Comply with requirements in this Section except when stricter requirements are specified in HVAC equipment schedules or Sections.

B. Comply with NEMA MG 1 unless otherwise indicated.

C. Retain paragraph below if severe-duty motors are required.

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

3.2 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 50 deg C.

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.

3.3 POLYPHASE MOTORS

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

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

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

   2. Motors 15HP and Larger: NEMA starting Code F or Code G.

   3. Motors Smaller than15 HP: Manufacturer's standard starting characteristic.

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

3.4 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, suited 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.

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

3.5 SINGLE-PHASE MOTORS

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

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

C. Bearings: Pre-lubricated, anti-friction ball bearings or sleeve bearings suitable for radial and thrust loading.

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

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

III. EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

PART 4 - GENERAL

4.1 RELATED DOCUMENTS

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

4.2 SUMMARY

A. Section Includes:

1. Flexible-hose pack less expansion joints.
2. Metal-bellows pack less expansion joints.
3. Grooved-joint expansion joints.
4. Alignment guides and anchors.

4.3 PERFORMANCE REQUIREMENTS

A. Compatibility: Products shall be suitable for piping service fluids, materials, working pressures, and temperatures.

B. Capability: Products to absorb 200 percent of maximum axial movement between anchors.

4.4 SUBMITTALS

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

B. Delegated-Design Submittal: For each anchor and alignment guide indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Design Calculations: Calculate requirements for thermal expansion of piping systems and for selecting and designing expansion joints, loops, and swing connections.
2. Anchor Details: Detail fabrication of each anchor indicated. Show dimensions and methods of assembly and attachment to building structure.
3. Alignment Guide Details: Detail field assembly and attachment to building structure.
4. Schedule: Indicate type, manufacturer's number, size, material, pressure rating, end connections, and location for each expansion joint.

C. Welding certificates.

D. Product Certificates: For each type of expansion joint, from manufacturer.

E. Maintenance Data: For expansion joints to include in maintenance manuals.

4.5 QUALITY ASSURANCE

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

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. ASME Boiler and Pressure Vessel Code: Section IX.

PART 5 - PRODUCTS

5.1 PACKLESS EXPANSION JOINTS

A. Flexible-Hose Pack less Expansion Joints:

A. Manufacturers: Subject to compliance with requirements, provide from the approved list of manufacturers.

B. Description: Manufactured assembly with inlet and outlet elbow fittings and two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose.

C. Flexible Hose: Corrugated-metal inner hoses and braided outer sheaths.

D. Expansion Joints for Steel Piping: Carbon-steel fittings with flanged end connections.

E. Stainless-steel hoses and double-braid, stainless-steel sheaths.

B. Metal-Bellows Pack less Expansion Joints:

F. Manufacturers: Subject to compliance with requirements provide from the approved list of manufacturers:

G. Standards: ASTM F 1120

H. Type: Circular, corrugated bellows with external tie rods.

I. Minimum Pressure: 1.5 times working pressure.

J. Configuration: Single joint with base unless otherwise indicated.

K. Expansion Joints for Copper Tubing: Single- or multi ply phosphor-bronze bellows, copper pipe ends, and brass shrouds.

(i). End Connections for Copper Tubing DN 50 and Smaller: Solder joint or threaded.

(ii). End Connections for Copper Tubing DN 65 and higher: Flanged.

L. Expansion Joints for Steel Piping: Single or multi-ply stainless-steel bellows, steel pipe ends, and carbon-steel shroud.

(i). End Connections for Steel Pipe DN 50 and Smaller : Threaded.

(ii). End Connections for Steel Pipe DN 65 and Larger : Flanged

5.2 GROOVED-JOINT EXPANSION JOINTS

A. Manufacturers: Subject to compliance with requirements, provide from approved manufacturer's list.

B. Description: Factory-assembled expansion joint made of several grooved-end pipe nipples, couplings, and grooved joints.

C. Standard: AWWA C606, for grooved joints.

D. Nipples: ASTM A 53/A 53M, Schedule 40, Type E or S, steel pipe with grooved ends.

E. Couplings: 5 or 7, flexible type for steel-pipe dimensions. Include ferrous housing sections, EPDM gasket suitable for cold and hot water, bolts and nuts.

5.3 ALIGNMENT GUIDES AND ANCHORS

A. Alignment Guides:

1. Manufacturers: Subject to compliance with requirements, provide from the approved list of manufacturers.

2. Description: Steel, factory-fabricated alignment guide, with bolted two-section outer cylinder and base for attaching to structure; with two-section guiding spider for bolting to pipe.

B. Anchor Materials:

C. Steel Shapes and Plates: ASTM A 36/A 36M.

D. Bolts and Nuts: ASME B18.10 or ASTM A 183, steel hex head.

E. Washers: ASTM F 844, steel, plain, flat washers.

F. Mechanical Fasteners: Insert wedge type stud with expansion plug anchor for use in hardened Portland cement concrete, with tension and shear capacities appropriate for application.

1. Stud: Threaded, zinc-coated carbon steel.
2. Expansion Plug: Zinc-coated steel.
3. Washer and Nut: Zinc-coated steel.

G. Chemical Fasteners: Insert-type-stud, bonding-system anchor for use with hardened Portland cement concrete, with tension and shear capacities appropriate for application.

1. Bonding Material: ASTM C 881/C 881M, Type IV, Grade 3, two-component epoxy resin suitable for surface temperature of hardened concrete where fastener is to be installed.
2. Stud: ASTM A 307, zinc-coated carbon steel with continuous thread on stud unless otherwise indicated.
3. Washer and Nut: Zinc-coated steel.

PART 6 - EXECUTION

6.1 EXPANSION-JOINT INSTALLATION

A. Install expansion joints of sizes matching sizes of piping in which they are installed.

B. Install packed-type expansion joints with packing suitable for fluid service.

C. Install metal-bellows expansion joints according to EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."

D. Install rubber packless expansion joints according to FSA-NMEJ-702.

E. Install grooved-joint expansion joints to grooved-end steel piping

6.2 ALIGNMENT-GUIDE AND ANCHOR INSTALLATION

A. Install alignment guides to guide expansion and to avoid end-loading and torsion stress.

B. Install one guide on each side of pipe expansion fittings and loops. Install guides nearest to expansion joint not more than 4 pipe diameters from expansion joint.

C. Attach guides to pipe and secure guides to building structure.

D. Install anchors at locations to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.

IV. SKEEVES AND SLEEVE SEALS FOR HVAC PIPING

PART 7 - GENERAL

7.1 RELATED DOCUMENTS

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

7.2 SUMMARY

A. Section Includes:

1. Sleeves.
2. Stack-sleeve fittings.

7.3 SUBMITTALS

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

PART 8 - PRODUCTS

8.1 SLEEVES

A. Galvanized-Steel Wall Pipes: ASTM A 53/A 53M, Schedule 40, with plain ends and welded steel collar; zinc coated.

B. Galvanized-Steel-Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, with plain ends.

PART 9 - EXECUTION

9.1 SLEEVE INSTALLATION

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

B. For sleeves that will have water tight requirements, select sleeves of size large enough to provide 25-mm annular clear space between piping and concrete slabs and walls.

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

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

a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 50 mm above finished floor level.

2. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.

D. Install sleeves for pipes passing through interior partitions.

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

2. Install sleeves that are large enough to provide 6.4-mm annular clear space between sleeve and pipe or pipe insulation.

3. Pack with 96 kg/cu. density fibreglass and caulk both ends with approved sealant.

E. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Pack annular space with 96 kg/cu.M (6 lbs/cu.ft.) density rockwool and caulk both ends with approved fire rated sealant pack.

F. Comply with requirements for fire stopping specified in Division 07 Section "Penetration Fire stopping."

9.2 SLEEVE- INSTALLATION

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

B. Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in centre of sleeve. Centre piping in penetration, and install in annular space between piping and sleeve.

9.3 SLEEVE SCHEDULE

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

1. Exterior Concrete Walls above Grade:

a. Galvanized-steel wall sleeves

2. Exterior Concrete Walls below Grade:

a. Galvanized-steel wall sleeves with water tight sealing

3. Concrete Slabs-on-Grade:

a. Galvanized-steel wall sleeves with water tight sealing.

4. Concrete Slabs above Grade:

a. Galvanized-Steel-Pipe Sleeves.

b. Interior Partitions:

c. Galvanized-Steel-Pipe Sleeves

V. METERS AND GAUGES FOR HVAC PIPING

PART 10 - GENERAL

10.1 RELATED DOCUMENTS

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

10.2 SUMMARY

A. Section Includes:

1. Bimetallic-actuated thermometers.
2. Liquid-in-glass thermometers.
3. Thermo wells.
4. Dial-type pressure gauges.
5. Gauge attachments.
6. Test plugs.
7. Test-plug kits.
8. Flow meters.

10.3 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 gauges to include in operation and maintenance manuals.

PART 11 - PRODUCTS

11.1 BIMETALLIC-ACTUATED THERMOMETERS

A. Manufacturers: Subject to compliance with requirements, provide from the approved list of manufacturers.

B. Standard: ASME B40.200.

C. Case: Liquid-filled and sealed type; stainless steel with 127-mm

D. Dial: Non reflective aluminum deg F and deg C.

E. Connector Type(s): Union joint, adjustable angle rigid with unified-inch screw threads.

F. Connector Size: 13 mm, with ASME B1.1 screw threads.

G. Stem: 6.4 or 9.4 mm in diameter; stainless steel.

H. Window: plastic.

I. Ring: Stainless steel.

J. Element: Bimetal coil.

K. Pointer: Dark-colored metal.

L. Accuracy: Plus or minus 1.5 percent of scale range.

11.2 LIQUID-IN-GLASS THERMOMETERS

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

1. Manufacturers: Subject to compliance with requirements, provide from the list of approved manufacturers:
2. Standard: ASME B40.200.
3. Case: Cast aluminum152-mm nominal size.
4. Case Form: Straight unless otherwise indicated.
5. Tube: Glass with magnifying lens and blue or red organic liquid.
6. Tube Background: Non reflective aluminum with permanently etched scale markings graduated in deg F and deg C.
7. Window: plastic.
8. Stem: brass and of length to suit installation.
9. Design for Air-Duct Installation: With ventilated shroud.
10. Connector: 19 mm, with ASME B1.1 screw threads.
11. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

11.3 PRESSURE GUAGES

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

1. Manufacturers: Subject to compliance with requirements, provide from the approved list of manufacturers:
2. Standard: ASME B40.100.
3. Case: Sealed Solid-front, pressure relief cast aluminum 152-mm nominal diameter.
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
5. Pressure Connection: Brass, with DN.
6. Movement: Mechanical, with link to pressure element and connection to pointer.

7. Dial: Non reflective aluminum with permanently etched scale markings graduated in psi and kPa.
8. Pointer: Dark-colored metal.
9. Window plastic material.
10. Ring: Brass

11.4 GUAGE ATTACHMENTS

A. Snubbers: ASME B40.100, brass; with DN 8. Include extension for use on insulated piping.
B. Siphons: Loop-shaped section of DN 8 with pipe threads.
C. Valves: Brass ball DN, ASME B1.20.1 pipe threads.

11.5 TEST PLUGS

A. Manufacturers: Subject to compliance with requirements,
B. Description: Test-station fitting made for insertion into piping tee fitting.
C. Body: Brass with core inserts and gasket and threaded cap. Include extended stem on units to be installed in insulated piping.
D. Thread Size: DN 8. ASME B1.20.1 pipe thread.
E. Minimum Pressure and Temperature Rating: 3450 kPa at 93 deg C

11.6 TEST-PLUG KITS

A. Manufacturers: Subject to compliance with requirements.
B. Furnish one test-plug kit containing two thermometers, one pressure gage and adapter, and carrying case. Thermometer sensing elements, pressure gage, and adapter probes shall be of diameter to fit test plugs and of length to project into piping.
C. Low-Range Thermometer: Small, bimetallic insertion type with 25- to 51-mm diameter dial and tapered-end sensing element. Dial range shall be at least minus 4 to plus 52 deg.
D. Pressure Gauge: Small, Bourdon-tube insertion type with 51- to 76-mm diameter dial and probe. Dial range shall be at least 0 to 1380 kPa.
E. Carrying Case: Metal or plastic, with formed instrument padding.

11.7 FLOWMETERS

A. Turbine Flow meters:
   1. Manufacturers: Subject to compliance with requirements, provide from the approved manufacturer’s list:
   2. Description: Flow meter with sensor and indicator.
   3. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.
   4. Sensor: Impeller turbine; for inserting into pipe fitting or for installing in piping and measuring flow directly liters per second.
   5. Design: Device or pipe fitting with inline turbine and integral direct-reading scale for water.
   6. Construction: Bronze body, with plastic turbine or impeller.
   7. Minimum Pressure Rating: 1035 kPa.
   8. Minimum Temperature Rating: 82 deg C.
   9. Indicator: Hand-held meter; either an integral part of sensor or a separate meter.
   10. Accuracy: Plus or minus 1-1/2 percent.

11. Display: Shows rate of flow, with register to indicate total volume in liters.

12. Operating Instructions: Include complete instructions with each flow meter.

B. Venturi Flowmeters:

1. Manufacturers: Subject to compliance with requirements, provide from the approved manufacturer's list.

2. Description: Flow meter with calibrated flow-measuring element, hoses or tubing, fittings, valves, indicator, and conversion chart.

3. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.

4. Sensor: Venturi-type, calibrated, flow-measuring element; for installation in piping.

   a. Design: Differential-pressure-type measurement for water.

   b. Construction: Bronze, brass, or factory-primed steel, with brass fittings and attached tag with flow conversion data.

   c. Minimum Pressure Rating: 1725 kPa.

   d. Maximum Temperature Rating: 121 deg C.

   e. End Connections for DN 50 and Smaller: Threaded.

   f. End Connections for DN 65 and Larger: Flanged or welded.

   g. Flow Range: Flow-measuring element and flow meter shall cover operating range of equipment or system served.

5. Permanent Indicators: Meter suitable for wall or bracket mounting, calibrated for connected flow meter element, and having 152-mm- diameter, or equivalent, dial with fittings and copper tubing for connecting to flow meter element.

   a. Scale: Liters per second.

   b. Accuracy: Plus or minus 1 percent.

6. Portable Indicators: Hand-held, differential-pressure type, calibrated for connected flow meter element and having two 3.7-m hoses, with carrying case.

   a. Scale: Liters per second.

   b. Accuracy: Plus or minus 2 percent between 20 and 80 percent of scale range.

7. Display: Shows rate of flow, with register to indicate total volume in liters.

8. Conversion Chart: Flow rate data compatible with sensor.

9. Operating Instructions: Include complete instructions with each flowmeter.

11.8 THERMAL-ENERGY METERS

A. Impeller-Turbine, Thermal-Energy Meters:

1. Manufacturers: Subject to compliance with requirements provide from the approved manufacturer's list.

2. Description: System with strainer, flow sensor, temperature sensors, transmitter, indicator, and connecting wiring.

3. Flow Sensor: Impeller turbine with corrosion-resistant-metal body and transmitter; for installing in piping.

   a. Design: Total thermal-energy measurement.

   b. Minimum Pressure Rating: 1035 kPa.

   c. Temperature Range: 5 to 121 deg C.

4. Temperature Sensors: Insertion-type transducer.

5. Indicator: Solid-state, integrating-type meter with integral battery pack; for wall mounting.
    a. Data Output: Six-digit electromechanical counter with readout in kilowatts per hour or joules.
    b. Battery Pack: Five-year lithium battery.
6. Accuracy: Plus or minus 1 percent.
7. Display: Visually indicates total fluid volume in liters and thermal-energy flow in kilowatts per hour or joules.
8. Strainer: Full size of main line piping.
9. Operating Instructions: Include complete instructions with each thermal-energy meter system.

PART 12 - EXECUTION

12.1 INSTALLATION

A. Install thermo wells with socket extending a minimum of 51 mm into fluid one-third of pipe diameter and in vertical position in piping tees.

B. Install thermo wells of sizes required to match thermometer connectors. Include bushings if required to match sizes.

C. Install thermo wells with extension on insulated piping.

D. Fill thermo wells with heat-transfer medium.

E. Install direct-mounted thermometers in thermo wells and adjust vertical and tilted positions.

F. Install duct-thermometer mounting brackets in walls of ducts. Attach to duct with screws.

G. Install direct-mounted pressure gauges in piping tees with pressure gage located on pipe at the most readable position.

H. Install remote-mounted pressure gauges on panel.

I. Install valve and snubber in piping for each pressure gauge for fluids (except steam).

J. Install valve and siphon fitting in piping for each pressure gauge for steam.

K. Install test plugs in piping tees.

L. Install flow indicators in piping systems in accessible positions for easy viewing.

M. Assemble and install connections, tubing, and accessories between flow-measuring elements and flow meters according to manufacturer's written instructions.

N. Install flow meter elements in accessible positions in piping systems.

O. Install wafer-orifice flow meter elements between pipe flanges.

P. Install differential-pressure-type flow meter elements, with at least minimum straight lengths of pipe, upstream and downstream from element according to manufacturer's written instructions.

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

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

S. Mount thermal-energy meters on wall if accessible; if not, provide brackets to support meters.

T. Install thermometers in the following locations:

1. Inlet and outlet of each hydronic zone.
2. Inlet and outlet of each hydronic boiler.
3. Two inlets and two outlets of each chiller.
4. Inlet and outlet of each hydronic coil in air-handling units.
5. Two inlets and two outlets of each hydronic heat exchanger.
6. Inlet and outlet of each thermal-storage tank.
7. Outside, return, supply, and mixed-air ducts.

U. Install pressure gauges in the following locations:

1. Discharge of each pressure-reducing valve.
2. Inlet and outlet of each chiller chilled-water and condenser-water connection.
3. Suction and discharge of each pump.
4. Inlet and outlet of each hydronic coil in air-handling units.
5. Inlet and outlet of each hydronic heat exchanger.

12.2 CONNECTIONS

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

B. Connect flow meter-system elements to meters.

C. Connect flow meter transmitters to meters.

D. Connect thermal-energy meter transmitters to meters.

12.3 ADJUSTING

A. After installation, calibrate meters according to manufacturer's written instructions.

B. Adjust faces of meters and gauges to proper angle for best visibility.

12.4 THERMOMETER SCHEDULE

A. Thermometers at inlet and outlet of each hydronic zone shall be of the following:

1. Compact style, liquid-in-glass type.

B. Thermometers at inlets and outlets of each chiller shall be of the following:

1. Compact style, liquid-in-glass type.

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

1. Compact style, liquid-in-glass type.

D. Thermometers at inlets and outlets of each hydronic heat exchanger shall be of the following

1. Compact style, liquid-in-glass type.

E. Thermometers at inlet and outlet of each hydronic heat-recovery unit shall be of the following:

1. Compact style, liquid-in-glass type.

F. Thermometers at outside-, return-, supply-, and mixed-air ducts shall be of the following:

1. Sealed, bimetallic-actuated type.

G. Thermometer stems shall be of length to match thermo well insertion length.

12.5 THERMOMETER SCALE-RANGE SCHEDULE

A. Scale Range for Chilled-Water Piping: minus 20 to plus 50 deg C.

B. Scale Range for Condenser-Water Piping: minus 20 to plus 50 deg C.

12.6 PRESSURE-GAGE SCALE-RANGE SCHEDULE

A. To suit to reflect readings depending on the system working pressure

VI. GENERAL DUTY VALVES FOR HVAC PIPING

PART 13 - GENERAL

13.1 RELATED DOCUMENTS

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

13.2 SUMMARY

A. Section Includes:

1. Bronze angle valves.
2. Bronze ball valves.
3. Iron, single-flange butterfly valves.
4. Iron, grooved-end butterfly valves.
5. Bronze swing check valves.
6. Iron swing check valves.
7. Iron, grooved-end swing-check valves.
8. Bronze gate valves.
9. Iron Gate valves.
10. Bronze globe valves.
11. Iron globe valves.

B. Related Sections:

1. Division 23 HVAC piping Sections for specialty valves applicable to those Sections only.
2. Division 23 Section "Identification for HVAC Piping and Equipment" for valve tags and schedules.

13.3 DEFINITIONS

A. CWP: Cold working pressure.

B. EPDM: Ethylene propylene copolymer rubber.

C. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.

D. NRS: Non rising stem.

E. OS&Y: Outside screw and yoke.

F. RS: Rising stem.

G. SWP: Steam working pressure.

13.4 SUBMITTALS

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

13.5 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. ASME Compliance:

1. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
2. ASME B31.1 for power piping valves.
3. ASME B31.9 for building services piping valves.

13.6 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, gate, and globe valves closed to prevent rattling.
4. Set ball and plug 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 hand wheels or stems as lifting or rigging points.

PART 14 - PRODUCTS

14.1 GENERAL REQUIREMENTS FOR VALVES

A. Refer to HVAC valve schedule for applications of valves.

B. Valve Pressure and Temperature Ratings: Not less than indicated and as required for system pressures and temperatures. (Pressure rating not less than PN16)

C. Valve Sizes: Same as upstream piping unless otherwise indicated.

D. Valve Actuator Types:

1. Gear Actuator: For quarter-turn valves DN 200 and larger.
2. Hand wheel: For valves other than quarter-turn types.
3. Hand lever: For quarter-turn DN 150 and smaller.
4. Wrench: For plug valves with square heads. Furnish Owner with 1 wrench for every 5 plug valves, for each size square plug-valve head.
5. Chain wheel: Device for attachment to valve hand wheel, stem, or other actuator; of size and with chain for mounting height, as indicated in the "Valve Installation" Article.

E. Valves in Insulated Piping: With 50-mm stem extensions and the following features:

1. Gate Valves: With rising stem.
2. Ball Valves: With extended operating handle of non-thermal conductive material, and protective sleeve that allows operation of valve without breaking the vapor seal or disturbing insulation.
3. Butterfly Valves: With extended neck.

F. Valve-End Connections:

1. Flanged: With flanges according to ASME B16.1 for iron valves.
2. Grooved: With grooves according to AWWA C606.
3. Solder Joint: With sockets according to ASME B16.18.
4. Threaded: With threads according to ASME B1.20.1.

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

14.2 BRONZE ANGLE VALVES

A. Class 125/150/200/300. Bronze Angle Valves with Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, provide from the list of approved manufacturers.
2. Description:
    a. Standard: MSS SP-80, Type 1.
    b. CWP Rating: as required.
    c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
    d. Ends: Threaded.
        1) Stem and Disc: Bronze.
        2) Packing: Asbestos free.
        3) Handwheel: Bronze

14.3 BRONZE BALL VALVES

A. Class 150/200/300 Retain one or more of eight paragraphs in this article if bronze ball valves are required. MSS SP-110 covers both brass and bronze, copper-alloy ball valves NPS 1/4 to

NPS 4 (DN 8 to DN 100). See the Evaluations and manufacturers' catalogs before selecting either brass or bronze ball valves or including both.

1. Manufacturers: Subject to compliance with requirements, Subject to compliance with requirements, provide from the list of approved manufacturers.
2. Description:
   a. Standard: MSS SP-110.
   b. Pressure rating: PN16
   c. Body Design: Two piece.
   d. Body Material: Bronze.
   e. Ends: Threaded.
   f. Seats: PTFE or TFE.
   g. Stem: Bronze.
   h. Ball: Stainless steel.
   i. Port: Full.

14.4 IRON, SINGLE-FLANGE BUTTERFLY VALVES

A. Class 150/200/300 CWP, Iron, Single-Flange Butterfly Valves with NBR Seat and Ductile-Iron Disc:

1. Manufacturers: Subject to compliance with requirements, Manufacturers: Subject to compliance with requirements, provide from approved list of Manufacturer's.
2. Description:
   a. Standard: MSS SP-67, Type I.
   b. Pressure rating: PN16
   c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
   d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
   e. Seat: NBR.
   f. Stem: piece stainless steel.
   g. Disc: Nickel-plated ductile iron

14.5 BRONZE SWING CHECK VALVES

A. Class 150/200/300, Bronze Swing Check Valves with Nonmetallic Disc:

1. Manufacturers: Subject to compliance with requirements, provide from approved list of Manufacturer's.
2. Description:
   a. Standard: MSS SP-80, Type 4.
   b. Pressure rating: PN16
   c. Body Design: Horizontal flow.
   d. Body Material: ASTM B 62, bronze.
   e. Ends: Threaded.
   f. Disc: PTFE or TFE.

14.6 IRON FLANGED/GROOVED SWING CHECK VALVES

A. Class 150/200/300, Iron, Dual-Plate Check Valves with Resilient Seat:

1. Manufacturers: Subject to compliance with requirements, provide from approved list of Manufacturer's.
2. Description:
   a. Standard: API 594.
   b. Pressure rating: PN16
   c. DN 65 to DN 300, CWP Rating: as required
   d. DN 350 to DN 600, CWP Rating: as required.
   e. Body Design: Wafer, spring-loaded plates.
   f. Body Material: ASTM A 126, gray iron.
   g. Seat: NBR

14.7 BRONZE GATE VALVES

A. Class 150/200/300, NRS Bronze Gate Valves:

1. Manufacturers: Subject to compliance with requirements, provide from approved list of Manufacturer's.
2. Description:
   a. Standard: MSS SP-80, Type 1.
   b. Pressure rating: PN16
   c. Body Material: ASTM B 62, bronze with integral seat and union-ring bonnet.
   d. Ends: Threaded.
   e. Stem: Bronze.
   f. Disc: Solid wedge; bronze.
   g. Packing: Asbestos free.
   h. Hand wheel: bronze

14.8 IRON GATE VALVES

A. Class 150/200/300, NRS, Iron Gate Valves:

1. Manufacturers: Subject to compliance with requirements, provide from approved list of Manufacturer's.
2. Description:
   a. Standard: MSS SP-70, Type I.
   b. Pressure rating: PN16
   c. DN 65 to DN 300, CWP Rating: as required.
   d. DN 350 to DN 600, CWP Rating: as required.
   e. Body Material: ASTM A 126, gray iron with bolted bonnet.
   f. Ends: Flanged.
   g. Trim: Bronze.
   h. Disc: Solid wedge.
   i. Packing and Gasket: Asbestos free

14.9 BRONZE GLOBE VALVES

A. Class 150/200/300, Iron Globe Valves:

1. Manufacturers: Subject to compliance with requirements, provide from approved list of Manufacturer's.
2. Description:

a. Standard: MSS SP-85, Type I.

b. Pressure rating: PN16.

c. Body Material: ASTM A 126, gray iron with bolted bonnet.

d. Ends: Flanged.

e. Trim: Bronze.

f. Packing and Gasket: Asbestos free

PART 15 - EXECUTION

15.1 EXAMINATION

A. Examine valve interior for cleanliness, freedom from foreign matter and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.

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

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

D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.

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

15.2 VALVE INSTALLATION

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

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

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

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

E. Install chain wheels on operators for valves DN 100 and larger and more than 2400 mm above floor. Extend chains to 1520 mm above finished floor.

F. Install check valves for proper direction of flow and as follows:

1. Swing Check Valves: In horizontal position with hinge pin level.

15.3 ADJUSTING

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

15.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

A. If valve applications are not indicated, use the following:

1. Shutoff Service: Ball, butterfly or gate valves.
2. Butterfly Valve Dead-End Service: Single-flange lug type.
3. Throttling Service: Globe valves.
4. Pump-Discharge Check Valves:
   a. DN 50 and Smaller: Bronze swing check valves with bronze disc.
   b. DN 65 and Larger: Iron swing check valves

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

C. Select valves, except wafer types, with the following end connections:

1. For Copper Tubing, DN 50 and Smaller: Threaded ends
2. For Copper Tubing, DN 65 to DN 100: Flanged ends
3. For Copper Tubing, DN 125 and Larger: Flanged ends.
4. For Steel Piping, DN 50 and Smaller: Threaded ends.
5. For Steel Piping, DN 65 to DN 100: Flanged ends

6. For Steel Piping, DN 125 and Larger: Flanged ends.
7. For Grooved-End Copper Tubing and Steel Piping, valve ends may be grooved.

15.5 CHILLED/CONDENSOR WATER VALVE SCHEDULE

A. Pipe DN 50 and Smaller:

1. Bronze Angle Valves
2. Ball Valves
3. Bronze Swing Check Valves
4. Bronze Gate Valves
5. Bronze Globe Valves

B. Pipe DN 65 and Larger:

1. Iron, Single-Flange Butterfly Valves for DN 65 to DN 300,
2. Iron, Single-Flange Butterfly Valves for DN 350 to DN 600.
3. Iron, Grooved-End Butterfly Valves, DN 65 to DN 300.
4. Iron, Grooved-End Check Valves, DN 65 to DN 300.
5. Iron, Plate-Type Check Valves: dual plate; resilient seat.
6. Iron Globe Valves:

VII. HANGERS & SUPPORTS FOR HVAC PIPING & EQUIPMENT

PART 16 - GENERAL

16.1 RELATED DOCUMENTS

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

16.2 SUMMARY

A. Section Includes:

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

B. Related Sections:

1. Division 23 Section "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
2. Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for vibration isolation devices.
3. Division 23 Section "Metal Ducts" for duct hangers and supports.

16.3 DEFINITIONS

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

16.4 PERFORMANCE REQUIREMENTS

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

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

C. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents and test water.

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

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

16.5 SUBMITTALS

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

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

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

C. Delegated-Design Submittal: For trapeze hangers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

D. Detail fabrication and assembly of trapeze hangers.

E. Design Calculations: Calculate requirements for designing trapeze hangers.

F. Welding certificates.

16.6 QUALITY ASSURANCE

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

B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

16.7 SCOPE OF WORK

A. MEP Contractor's scope of work defined hereunder shall comply with the requirement of this section and all other related product sections, which are part or partly considered of the HVAC works in general.

B. The contractor shall have the responsibility, resources, technical capabilities and financial support to:

1. Study all contract drawings, documents, specifications and instruction provided within various stages of tender and to understand design content and requirements of all systems and allow for all works, equipment's, material, instruments, tools necessary for the project.
2. Procure, examine, install, test, commission and handover full and complete operational and functional support system comply with the specifications and manufacturer requirements, all as showing on drawings and defined in specifications not limited to drawings schedules.
3. MEP contractor shall allow for specialist third party designer to check confirm and design the support system for chilled water, cooling tower piping, steam piping and all other piping systems from 200mm dia. and above. The design shall ensure proper support and hangers that provide system protection to the system and building considering all operational weights and pressures.

PART 17 - PRODUCTS

17.1 METAL PIPE HANGERS AND SUPPORTS

A. Carbon-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
2. Galvanized Metallic Coatings: Pre-galvanized or hot dipped.
3. Non-metallic Coatings: Plastic coating, jacket or liner.
4. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
5. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel.

B. Stainless-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
2. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
3. Hanger Rods: Continuous-thread rod, nuts, and washer made of stainless steel.

C. Copper Pipe Hangers:

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

17.2 TRAPEZE PIPE HANGERS

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

17.3 METAL FRAMING SYSTEMS

A. MFMA Manufacturer Metal Framing Systems:

1. Description: Shop- or field-fabricated pipe-support assembly for supporting multiple parallel pipes.
2. Standard: MFMA-4.
3. Channels: Continuous slotted steel channel with inturned lips.
4. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
5. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel or stainless-steel dependent on application.
6. Metallic Coating: Hot-dipped galvanized.
7. Paint Coating: Vinyl, Epoxy or Polyester.
8. Plastic Coating: Polyurethane, Epoxy or Polyester.

B. Non-MFMA Manufacturer Metal Framing Systems:

M. Description: Shop- or field-fabricated pipe-support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.

N. Standard: Comply with MFMA-4.

O. Channels: Continuous slotted steel channel with inturned lips.

P. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.

Q. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel or stainless-steel dependant on application.

R. Coating: Zinc or Paint.

17.4 THERMAL-HANGER SHIELD INSERTS

A. Insulation-Insert Material for Cold Piping: ASTM C 552, Type II cellular glass with 100-psig (688-kPa) or ASTM C 591, Type VI, Grade 1 phenolic with 125-psig (862-kPa) minimum compressive strength and vapor barrier.

B. Insulation-Insert Material for Hot Piping: ASTM C 552, Type II cellular glass with 100-psig (688-kPa) or ASTM C 591, Type VI, Grade 1 phenolic with 125-psig (862-kPa) minimum compressive strength.

C. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.

D. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.

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

17.5 FASTENER SYSTEMS

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

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

17.6 PIPE STANDS

A. General Requirements for Pipe Stands: Shop- or field-fabricated assemblies made of manufactured corrosion-resistant components to support roof-mounted piping.

B. Compact Pipe Stand: One-piece plastic unit with integral-rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.

C. Low-Type, Single-Pipe Stand: One-piece stainless-steel base unit with plastic roller, for roof installation without membrane penetration.

D. High-Type, Single-Pipe Stand:

1. Description: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.
2. Base: Stainless steel.
3. Vertical Members: Two or more cadmium-plated-steel or stainless-steel.
4. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with plastic or stainless-steel, roller-type pipe support.

E. High-Type, Multiple-Pipe Stand:

1. Description: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.
2. Bases: One or more; stainless steel.
3. Vertical Members: Two or more protective-coated-steel channels.

4. Horizontal Member: Protective-coated-steel channel.

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

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

17.7 EQUIPMENT SUPPORTS

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

17.8 MISCELLANEOUS MATERIALS

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

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

1. Properties: Non-staining, noncorrosive, and nongaseous.

2. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength

PART 18 - EXECUTION

18.1 HANGER AND SUPPORT INSTALLATION

A. Metal 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 the building structure.

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

C. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.

D. Field fabricate from ASTM A 36/A 36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.

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

F. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.

G. Fastener System Installation:

1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches (100 mm) thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.

2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

H. Pipe Stand Installation:

1. Pipe Stand Types except Curb-Mounted Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.

2. Curb-Mounted-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. See Division 07 Section "Roof Accessories" for curbs.

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

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

K. 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.

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

M. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 (DN 65) and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

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

O. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.

P. Insulated Piping:

1. Attach clamps and spacers to piping.

   a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.

   b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.

   c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.

2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.

   a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 (DN 100) and larger if pipe is installed on rollers.

3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.

   a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 (DN 100) and larger if pipe is installed on rollers.

4. Shield Dimensions for Pipe: Not less than the following:

   a. NPS 1/4 to NPS 3-1/2 (DN 8 to DN 90): 12 inches (305 mm) long and 0.048 inch (1.22 mm) thick.

   b. NPS 4 (DN 100): 12 inches (305 mm) long and 0.06 inch (1.52 mm) thick.

   c. NPS 5 and NPS 6 (DN 125 and DN 150): 18 inches (457 mm) long and 0.06 inch (1.52 mm) thick.

   d. NPS 8 to NPS 14 (DN 200 to DN 350): 24 inches (610 mm) long and 0.075 inch (1.91 mm) thick.

   e. NPS 16 to NPS 24 (DN 400 to DN 600): 24 inches (610 mm) long and 0.105 inch (2.67 mm) thick.

5. Pipes NPS 8 (DN 200) and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.

6. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

18.2 EQUIPMENT SUPPORTS

1. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.

2. Grouting: Place grout under supports for equipment and make bearing surface smooth.

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

18.3 METAL FABRICATIONS

1. Cut, drill and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.

2. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.

3. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:

   a. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.

b. Obtain fusion without undercut or overlap.

c. Remove welding flux immediately.

d. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

18.4 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches (40 mm).

18.5 PAINTING

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

B. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils (0.05 mm).

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

18.6 HANGER AND SUPPORT SCHEDULE

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

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

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

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

E. Use carbon-steel pipe hangers and supports, or metal framing systems and attachments for general service applications.

F. Use stainless-steel pipe hangers and stainless-steel attachments for hostile environment applications.

G. Use copper-plated pipe hangers and copper attachments for copper piping and tubing.

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

I. Use thermal-hanger shield inserts for insulated piping and tubing.

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

1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of non-insulated or insulated, stationary pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).

2. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes NPS 3/4 to NPS 36 (DN 20 to DN 900), requiring clamp flexibility and up to 4 inches (100 mm) of insulation.

3. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes NPS 1/2 to NPS 24 (DN 15 to DN 600) if little or no insulation is required.

4. Pipe Hangers (MSS Type 5): For suspension of pipes NPS 1/2 to NPS 4 (DN 15 to DN 100), to allow off centre closure for hanger installation before pipe erection.

5. Adjustable, Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of non-insulated, stationary pipes NPS 3/4 to NPS 8 (DN 20 to DN 200).
6. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
7. Adjustable Band Hangers (MSS Type 9): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
8. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of non-insulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
9. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of non-insulated, stationary pipes NPS 3/8 to NPS 8 (DN 10 to DN 200).
10. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of non-insulated, stationary pipes NPS 3/8 to NPS 3 (DN 10 to DN 80).
11. U-Bolts (MSS Type 24): For support of heavy pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).
12. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
13. Pipe Saddle Supports (MSS Type 36): For support of pipes NPS 4 to NPS 36 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate.
14. Pipe Stanchion Saddles (MSS Type 37): For support of pipes NPS 4 to NPS 36 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate, and with U-bolt to retain pipe.
15. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes NPS 2-1/2 to NPS 36 (DN 65 to DN 900) if vertical adjustment is required, with steel-pipe base stanchion support and cast-iron floor flange.
16. Single-Pipe Rolls (MSS Type 41): For suspension of pipes NPS 1 to NPS 30 (DN 25 to DN 750), from two rods if longitudinal movement caused by expansion and contraction might occur.
17. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes NPS 2-1/2 to NPS 24 (DN 65 to DN 600), from single rod if horizontal movement caused by expansion and contraction might occur.
18. Complete Pipe Rolls (MSS Type 44): For support of pipes NPS 2 to NPS 42 (DN 50 to DN 1050) if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
19. Pipe Roll and Plate Units (MSS Type 45): For support of pipes NPS 2 to NPS 24 (DN 50 to DN 600) if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
20. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes NPS 2 to NPS 30 (DN 50 to DN 750) if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

K. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24 (DN 24 to DN 600).

2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers NPS 3/4 to NPS 24 (DN 20 to DN 600) if longer ends are required for riser clamps.

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

1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches (150 mm) for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450 deg F (49 to 232 deg C) piping installations.
3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F (49 to 232 deg C) piping installations.

M. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction, to attach to top flange of structural shape.
3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
6. C-Clamps (MSS Type 23): For structural shapes.
7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
11. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
12. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
    a. Light (MSS Type 31): 750 lb (340 kg).
    b. Medium (MSS Type 32): 1500 lb (680 kg).
    c. Heavy (MSS Type 33): 3000 lb (1360 kg).
13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

N. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.

O. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches (32 mm).
3. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41, roll hanger with springs.
4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
5. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.
6. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.
7. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.
8. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
   a. Horizontal (MSS Type 54) : Mounted horizontally.
   b. Vertical (MSS Type 55) : Mounted vertically.
   c. Trapeze (MSS Type 56) : Two vertical-type supports and one trapeze member.

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

Q. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.

R. Use powder-actuated fasteners or mechanical-expansion anchors instead of building attachments where required in concrete construction. Confirm use of fasteners and anchors with the structural engineer.

VIII. VIBRATION & SEISMIC CONTROLS FOR HVAC PIPING & EQUIPMENT

PART 19 - GENERAL

19.1 RELATED DOCUMENTS

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

19.2 SUMMARY

A. This Section includes the following:

1. Adjust list below to suit Project.
2. Isolation pads.
3. Isolation mounts.
4. Restrained elastomeric isolation mounts.
5. Freestanding and restrained spring isolators.
6. Housed spring mounts.
7. Elastomeric hangers.
8. Spring hangers.
9. Spring hangers with vertical-limit stops.
10. Pipe riser resilient supports.
11. Resilient pipe guides.
12. Freestanding and restrained air-mounting system.
13. Restrained vibration isolation roof-curb rails.
14. Seismic snubbers.
15. Restraining braces and cables.
16. Inertia vibration isolation equipment bases.

19.3 DEFINITIONS

A. IBC: International Building Code.

B. ICC-ES: ICC-Evaluation Service.

C. OSHPD: Office of Statewide Health Planning and Development for the State of California.

19.4 PERFORMANCE REQUIREMENTS

A. Wind-Restraint Loading:

1. Basic Wind Speed: <TBC>.
2. Building Classification Category: III
3. Minimum 10 lb/sq. ft. (48.8 kg/sq. m) multiplied by the maximum area of the HVAC component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.

19.5 SUBMITTALS

A. Product Data: For the following:

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of seismic-restraint component used.

3. Tabulate types and sizes of seismic restraints, complete with report numbers and rated strength in tension and shear as evaluated by an agency acceptable to authorities having jurisdiction.
4. Annotate to indicate application of each product submitted and compliance with requirements.

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

C. Delegated-Design Submittal: For vibration isolation and seismic-restraint details indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

D. Design Calculations: Calculate static and dynamic loading due to equipment weight and operation, seismic and wind forces required to select vibration isolators, seismic and wind restraints, and for designing vibration isolation bases.

E. Coordinate design calculations with wind load calculations required for equipment mounted outdoors. Comply with requirements in other Division 23 Sections for equipment mounted outdoors.

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

G. Vibration Isolation Base Details: Detail overall dimensions, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, base weights, equipment static loads, power transmission, component misalignment, and cantilever loads.

H. Seismic- and Wind-Restraint Details:
1. Design Analysis: To support selection and arrangement of seismic and wind restraints. Include calculations of combined tensile and shear loads.
2. Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.
3. Coordinate seismic-restraint and vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply with requirements in other Division 23 Sections for equipment mounted outdoors.

I. Coordination Drawings: Show coordination of seismic bracing for HVAC piping and equipment with other systems and equipment in the vicinity, including other supports and seismic restraints.

J. Welding certificates.

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

L. Field quality-control test reports.

M. Operation and Maintenance Data: For air-mounting systems to include in operation and maintenance manuals.

N. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

19.6 QUALITY ASSURANCE

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

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

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

D. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval OPA number from OSHPD, preapproval by ICC-ES, or preapproval by another agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are not available, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.

PART 20 - PRODUCTS

20.1 VIBRATION ISOLATORS

A. Available Manufacturers: Subject to compliance with requirements.

B. Pads: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a non-slip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.

C. Mounts" Double-deflection type, with molded, oil-resistant rubber, hermetically sealed compressed fiberglass, or neoprene isolator elements with factory-drilled, encapsulated top plate for bolting to equipment and with baseplate for bolting to structure. Color-code or otherwise identify to indicate capacity range.

1. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.
2. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.

D. Spring Isolators: Freestanding, laterally stable, open-spring isolators.

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

E. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic or limit-stop restraint.

1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to 1/4-inch- (6-mm-) thick, neoprene or rubber isolator pad attached to baseplate underside; and adjustable equipment mounting and levelling bolt that acts as blocking during installation.
2. Restraint: Seismic or limit stop as required for equipment and authorities having jurisdiction.
3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

F. Housed Spring Mounts: Housed spring isolator with integral seismic snubbers.

1. Housing: Ductile-iron or steel housing to provide all-directional seismic restraint.
2. Base: Factory drilled for bolting to structure.
3. Snubbers: Vertically adjustable to allow a maximum of 1/4-inch (6-mm) travel up or down before contacting a resilient collar.

G. Spring Hangers Combination coil-spring and elastomeric-insert hanger with spring and insert in compression.

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

H. Spring Hangers with Vertical-Limit Stop: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression and with a vertical-limit stop.

1. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
7. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
8. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

20.2 AIR-MOUNTING SYSTEMS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

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

C. Basis-of-Design Product: Subject to compliance with requirements, provide for a comparable product by one of the following:

D. Air Mounts: Freestanding, single or multiple, compressed-air bellows.

1. Assembly: Upper and lower steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows.
2. Maximum Natural Frequency: 3 Hz.
3. Operating Pressure Range: 25 to 100 psig (172 to 690 kPa).
4. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
5. Levelling Valves: Minimum of 3 required to maintain levelling within plus or minus 1/8 inch (3 mm).

E. Restrained Air Mounts <Insert drawing designation>: Housed compressed-air bellows.

1. Assembly: Upper and lower steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows and spring, with angle-iron frame having vertical-limit stops and channel-section top with levelling adjustment and attachment screws.
2. Maximum Natural Frequency: 3 Hz.
3. Operating Pressure Range: 25 to 100 psig (172 to 690 kPa).
4. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
5. Levelling Valves: Minimum of 3 required to maintain levelling within plus or minus 1/8 inch (3 mm).

20.3 RESTRAINED VIBRATION ISOLATION ROOF-CURB RAILS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

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

C. General Requirements for Restrained Vibration Isolation Roof-Curb Rails: Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment and to withstand seismic and wind forces.

D. Lower Support Assembly: Formed sheet-metal section containing adjustable and removable steel springs that support upper frame. Upper frame shall provide continuous support for equipment and shall be captive to resiliently resist seismic [and wind] forces. Lower support assembly shall have a means for attaching to building structure and a wood nailer for attaching roof materials, and shall be insulated with a minimum of 2 inches (50 mm) of rigid, glass-fibre insulation on inside of assembly.

E. Spring Isolators: Adjustable, restrained spring isolators shall be mounted on 1/4-inch- (6-mm-) thick, elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with the integrity of the roof.

1. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic [or wind] restraint.
    a. Housing: Steel with resilient vertical-limit stops and adjustable equipment mounting and levelling bolt.
    b. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.

c. Minimum Additional Travel: 50 percent of the required deflection at rated load.

d. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

e. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2. Pads: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.

F. Snubber Bushings: All-directional, elastomeric snubber bushings at least 1/4 inch (6 mm) thick.

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

20.4 VIBRATION ISOLATION EQUIPMENT BASES

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

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

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.

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

3. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.

4. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

C. Inertia Base Factory-fabricated, welded, structural-steel bases and rails ready for placement of cast-in-place concrete.

1. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.

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

3. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.

4. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

5. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.

PART 21 - EXECUTION

21.1 EXAMINATION

A. Examine areas and equipment to receive vibration isolation and seismic control devices for compliance with requirements for installation tolerances and other conditions affecting performance.

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

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

21.2 APPLICATIONS

A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by an agency acceptable to authorities having jurisdiction.

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

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

21.3 VIBRATION-CONTROL AND SEISMIC-RESTRAINT DEVICE INSTALLATION

A. Equipment Restraints:

1. Install seismic snubbers on HVAC equipment mounted on vibration isolators. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.
2. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch (3.2 mm).
3. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction providing required submittals for component.

B. Piping Restraints:

1. Comply with requirements in MSS SP-127.
2. Space lateral supports a maximum of 40 feet (12 m)
3. Brace a change of direction longer than 12 feet (3.7 m).

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

D. Install seismic-restraint devices using methods approved by an evaluation service member of an agency acceptable to authorities having jurisdiction] providing required submittals for component.

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

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

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

H. Drilled-in Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling.

Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid pre-stressed tendons, electrical and telecommunications conduit, and gas lines.

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

21.4 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

A. Install flexible connections in piping where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment. Comply with requirements in Division 23 Section "Hydronic Piping" for piping flexible connections.

21.5 FIELD QUALITY CONTROL

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

B. Perform tests and inspections.

C. Tests and Inspections:

1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
2. Schedule test with Owner, through Architect, before connecting anchorage device to restrained component (unless post-connection testing has been approved), and with at least seven days' advance notice.
3. Obtain Architect's approval before transmitting test loads to structure. Provide temporary load-spreading members.
4. Test at least four of each type and size of installed anchors and fasteners selected by Architect.
5. Test to 90 percent of rated proof load of device.
6. Measure isolator restraint clearance.
7. Measure isolator deflection.
8. Verify snubber minimum clearances.
9. Air-Mounting System Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
10. Air-Mounting System Operational Test: Test the compressed-air levelling system.
11. Test and adjust air-mounting system controls and safeties.

12. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.

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

E. Prepare test and inspection reports.

21.6 ADJUSTING

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

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

C. Adjust air-spring levelling mechanism.

D. Adjust active height of spring isolators.

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

21.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-mounting systems.

IX. MECHANICAL IDENTIFICATION

PART 22 - GENERAL

22.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and the following sections of the specification

22.2 SUMMARY

A. This Section includes guidelines as to the type, materials and size of labels required to identify all mechanical equipment.

22.3 REFERENCES

A. ASHRAE/IESNA 90.1-2004 Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2004, Section 6 - "Heating, Ventilating, and Air-Conditioning."

22.4 SUBMITTALS

A. Refer MECHANICAL GENERAL REQUIREMENTS.

22.5 COORDINATION

A. Coordinate installation of identifying devices with completion of covering and painting of surfaces.

B. Coordinate installation of identifying devices with locations of access panels and doors.

C. Install identifying devices before installing acoustical ceilings and similar concealment.

22.6 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of condensing units that fails in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:
2. Warranty Period: 2 year from date of Substantial Completion.

22.7 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

PART 23 - PRODUCTS

23.1 EQUIPMENT LABELS

A. Provide machine-engraved brass or black anodized aluminium nameplates to identify each major equipment item.

B. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).

C. Lettering shall be black on white background, unless expressly specified otherwise.

D. Nameplates for major equipment shall be engraved in lettering 16 mm in height.

E. Uniquely identify such materials using a numbering system similar to that shown on the Drawings for major equipment items. Uniquely list such materials in the Operating and Maintenance Manual.

F. Attach labels by instant adhesive or stainless-steel rivets. Do not mount labels on removable covers. Attach labels to valves with chromium plated brass chain.

23.2 WARNING SIGNS AND LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1.6 mm thick, and having predrilled holes for attachment hardware.

B. Letter Color: White

C. Background Color: Red

D. Minimum Label Size: Length and width vary for required label content, but not less than 64 by 19 mm.

E. Minimum Letter Size: 6.4 mm for name of units if viewing distance is less than 600 mm, 13 mm for viewing distances up to 1830 mm, and proportionately larger lettering for greater viewing distances.

F. Fasteners: Stainless-steel rivets or self-tapping screws

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

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

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

2. Lettering Size: At least 38 mm high.

23.3 ANCILLARY EQUIPMENT LABELS

A. Tags shall be provided to identify and indicate the function of ancillary equipment such as gauges, valves (isolating - including whether normally open or closed, balancing, regulating, check and control), strainers, water flow measuring devices, flow switches, balancing and motorized dampers, fire dampers or other equipment requiring periodic inspection.

B. Brass or black anodized aluminium nameplates to identify each of these items

C. Tags shall be stamped or engraved with 6.4 mm high lettering. The minimum size for labels shall be 65 mm x 12 mm.

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

23.4 DUCTWORK AND PIPE WORK LABELS

A. Install plastic-laminated labels with permanent adhesive on all pipes and ducts.

B. Include identification of pipes and ducts using the same designations or abbreviations as on the drawings. Text shall also indicate the pipe size, and an arrow indicating flow direction.

C. Lettering size to be at least 38 mm high and the direction of flow shall be indicated by an arrow of length 3 x diameter of pipe and its insulation.

D. Locate labels near points where ducts and pipes enter into concealed spaces and at maximum intervals of 15 m in each space where ducts are exposed or concealed by removable ceiling system.

E. Located pipe labels near control devices and each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.

23.5 MOTOR CONTROL CENTERS

A. Equipment labels for 400 A or larger Motor Control Centers (MCCs) shall include equipment designation, manufacturer's name, type designation or other traceable identification number (to enable the operator to obtain relevant information from the manufacturer), bus bar rating, fault level, and duration of fault. Locate labels in a prominent position adjacent to the main switch.

B. Label each way of switchboards, distribution boards and motor control centers with phase and circuit number.

C. Label motor starters with name and size of load.

D. Provide typed or stenciled schedules, listing circuit number, fuse/MCBs rating, and service, for each switchboard, distribution board and motor control center. Insert into a plastic sleeve fixed on the inside of the switchboard door.

E. Provide an as-installed single line drawing of the electrical distribution system, laminated and fixed in the main switch room.

PART 24 - EXECUTION

24.1 INSTALLATION

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

B. Install or permanently fasten labels on each major item of mechanical equipment.

C. Locate equipment labels where accessible and visible.

24.2 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment.

B. Locate equipment labels where accessible and visible.

24.3 PIPE LABEL INSTALLATION

A. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 15 m along each run. Reduce intervals to 7.6 m in areas of congested piping and equipment.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

B. Pipe Label Color Schedule:

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

b. Letter Color: Green.

24.4 DUCT LABEL INSTALLATION

A. Install plastic-laminated self-adhesive duct labels with permanent adhesive on air ducts in the following color codes:

1. Blue: For cold-air supply ducts.

2. Yellow: For hot-air supply ducts.

3. Green: For exhaust-, outside-, relief-, return-, and mixed-air ducts.

4. ASME A13.1 Colors and Designs: For hazardous material exhaust.

B. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of 15 m in each space where ducts are exposed or concealed by removable ceiling system.

24.5 VALVE-TAG INSTALLATION

A. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.

B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:

24.6 WARNING-TAG INSTALLATION

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

X. TESTING, ADJUSTING AND BALANCING FOR HVAC

PART 25 - GENERAL

25.1 RELATED DOCUMENTS

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

25.2 SUMMARY

A. Section Includes:

1. Balancing Air Systems:

a. Constant-volume air systems.

b. Dual-duct systems.

c. Variable-air-volume systems.

d. Multi zone systems.

e. Induction-unit systems.

2. Balancing Hydronic Piping Systems:

a. Constant-flow hydronic systems.

b. Variable-flow hydronic systems.

c. Primary-secondary hydronic systems.

25.3 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. NEBB: National Environmental Balancing Bureau.

C. TAB: Testing, adjusting, and balancing.

D. TABB: Testing, Adjusting, and Balancing Bureau.

E. TAB Specialist: An entity engaged to perform TAB Work.

25.4 SUBMITTALS

A. Qualification Data: Within 15 days of Contractor's Notice to Proceed, submit documentation that the TAB contractor and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

B. Contract Documents Examination Report: Within 15 days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: 30 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.

D. Certified TAB reports.

E. Sample report forms.

F. Instrument calibration reports, to include the following:

1. Instrument type and make.

2. Serial number.

3. Application.

4. Dates of use.

5. Dates of calibration.

25.5 QUALITY ASSURANCE

A. TAB Contractor Qualifications: Engage a TAB entity from the approved list.

1. TAB Field Supervisor: Employee of the TAB contractor and approved by the Engineer.
2. TAB Technician: Employee of the TAB contractor and approved by the Engineer as a TAB technician.

B. TAB Conference: Meet with the Main Contractor, Client Representative, Contractor and the Engineer on approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Require the participation of the TAB field supervisor and technicians. Provide seven days' advance notice of scheduled meeting time and location.

1. Agenda Items:
    a. The Contract Documents examination report.
    b. The TAB plan.
    c. Coordination and cooperation of trades and subcontractors.
    d. Coordination of documentation and communication flow.

C. Certify TAB field data reports and perform the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
2. Certify that the TAB team complied with the approved TAB plan and the procedures specified and referenced in this Specification.

D. TAB Report Forms: Use standard TAB contractor's forms, customized to capture site and specification requirements, approved by the Engineer.

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

25.6 PROJECT CONDITIONS

A. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

25.7 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 26 - EXECUTION

26.1 TAB SPECIALISTS

A. Subject to compliance with requirements, engage one of the TAB from the approved list.

26.2 EXAMINATION

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

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

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

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

E. Examine ceiling plenums and under floor air plenums used for supply, return, or relief air to verify that they meet the leakage class of connected ducts as specified in Division 23 Section "Metal Ducts" and are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

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

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

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

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

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

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

J. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

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

L. Examine two-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.

26.3 PREPARATION

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

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

1. Permanent electrical-power wiring is complete.
2. 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.

26.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Contractor is responsible to provide all utilities and services required for TAB (electrical power, water etc.) if not available at the time of TAB.

B. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance"/ ASHRAE 111/ SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing" and in this Section.

C. Comply with requirements in ASHRAE 62.1-2004, Section 7.2.2, and “Air Balancing."

D. 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 same material and thickness as used to construct ducts.
2. After testing and balancing, install test ports and duct access doors that comply with requirements in Division 23 Section "Air Duct Accessories."
3. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Division 23 Section "HVAC Insulation."

E. 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.

F. Take and report testing and balancing measurements in IP and metric SI units.

26.5 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

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

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

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

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

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

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

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

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

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

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

L. Verify that air duct system is sealed as specified in Division 23 Section "Metal Ducts."

26.6 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 calculates the total airflow.

2. Measure fan static pressures as follows to determine actual static pressure:

a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.

b. Measure static pressure directly at the fan outlet or through the flexible connection.

c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.

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

3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

a. Report the cleanliness status of filters and the time static pressures are measured.

4. Measure static pressures entering and leaving other devices, 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 the Engineer for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in Division 23 Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

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

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

1. Measure airflow of sub main and branch ducts.

a. Where sufficient space in sub main 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 sub main and branch duct after all have been adjusted. Continue to adjust sub main and branch ducts to indicated airflows within specified tolerances.

C. Measure air outlets and inlets without making adjustments

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

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

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

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

26.7 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at minimum set-point airflow with the remainder at maximum-airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.

B. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set outdoor-air dampers at minimum, and set return- and exhaust-air dampers at a position that simulates full-cooling load.

2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.

3. Measure total system airflow. Adjust to within indicated airflow.

4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.

5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.

a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.

6. Re measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.

8. Record final fan-performance data.

C. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance variable-air-volume systems the same as described for constant-volume air systems.

2. Set terminal units and supply fan at full-airflow condition.

3. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.

4. Readjust fan airflow for final maximum readings.

5. Measure operating static pressure at the sensor that controls the supply fan if one is installed, and verify operation of the static-pressure controller.

6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.

7. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.

a. If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.

8. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

D. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.

2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.

3. Set terminal units at full-airflow condition.

4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.

5. Adjust terminal units for minimum airflow.

6. Measure static pressure at the sensor.

7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

26.8 PROCEDURES FOR MULTIZONE SYSTEMS

1. Set unit at maximum airflow through the cooling coil.
2. Adjust each zone's balancing damper to achieve indicated airflow within the zone.

26.9 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

1. 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.
2. Prepare schematic diagrams of systems' "as-built" piping layouts.
3. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:
   a. Open all manual valves for maximum flow.
   b. Check liquid level in expansion tank.
   c. Check makeup water-station pressure gage for adequate pressure for highest vent.
   d. Check flow-control valves for specified sequence of operation, and set at indicated flow.
4. 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.
5. Set system controls so automatic valves are wide open to heat exchangers.
6. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
7. Check air vents for a forceful liquid flow exiting from vents when manually operated.

26.10 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 the Engineer and comply with requirements in Division 23 Section "Hydronic Pumps."
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 plus or minus 10 percent 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 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 percent 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, and rpm, pump heads, and systems' 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.

26.11 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.

26.12 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

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

26.13 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.

26.14 PROCEDURES FOR CHILLERS

A. Balance water flow through each evaporator 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. Verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

26.15 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 steam coil:

1. Dry-bulb temperature of entering and leaving air.
2. Airflow.
3. Air pressure drop.
4. Inlet steam pressure.

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

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

26.16 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 percent, make equipment adjustments to achieve the calculated rates. If increase or decrease is 5 percent or less, equipment adjustments are not required.
4. Balance each air outlet.

26.17 TOLERANCES

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

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

26.18 REPORTING

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

B. Status Reports: Prepare weekly and monthly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

26.19 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 at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.

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

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

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

1. Title page.
2. Name and address of the TAB contractor.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB supervisor who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:
    a. Indicated versus final performance.
    a. Notable characteristics of systems.
    b. Description of system operation sequence if it varies from the Contract Documents.
12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans and pump performance forms including the following:
    a. Settings for outdoor-, return-, and exhaust-air dampers.
    a. Conditions of filters.
    b. Cooling coil, wet- and dry-bulb conditions.

c. Face and bypass damper settings at coils.

d. Fan drive settings including settings and percentage of maximum pitch diameter.

e. Inlet vane settings for variable-air-volume systems.

f. Settings for supply-air, static-pressure controller.

g. 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. Number, make, and size of belts.
   i. 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.
3. Test Data (Indicated and Actual Values):
   a. Total air flow rate in cfm (L/s).
   b. Total system static pressure in inches wg (Pa).
   c. Fan rpm.
   d. Discharge static pressure in inches wg (Pa).
   e. Filter static-pressure differential in inches wg (Pa).
   f. Cooling-coil static-pressure differential in inches wg (Pa).
   g. Outdoor airflow in cfm (L/s).
   h. Return airflow in cfm (L/s).
   i. Outdoor-air damper position.
   j. Return-air damper position.
   k. Vortex damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:

   a. System identification.
   b. Location.
   c. Coil type.
   d. Number of rows.
   e. Fin spacing in fins per inch (mm) o.c.
   f. Make and model number.
   g. Face area in sq. ft. (sq. m).
   h. Tube size in NPS (DN).
   i. Tube and fin materials.
   j. Circuiting arrangement.

G. Test Data (Indicated and Actual Values):

   a. Air flow rate in cfm (L/s).
   b. Average face velocity in fpm (m/s).
   c. Air pressure drop in inches wg (Pa).
   d. Outdoor-air, wet- and dry-bulb temperatures in deg F (deg C).
   e. Return-air, wet- and dry-bulb temperatures in deg F (deg C).
   f. Entering-air, wet- and dry-bulb temperatures in deg F (deg C).
   g. Leaving-air, wet- and dry-bulb temperatures in deg F (deg C).
   h. Water flow rate in gpm (L/s).
   i. Water pressure differential in feet of head or psig (kPa).
   j. Entering-water temperature in deg F (deg C).
   k. Leaving-water temperature in deg F (deg C).

H. 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. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).

2. Motor Data:

   a. Motor make, and frame type and size.
   b. Horsepower and rpm.
   c. Volts, phase, and hertz.
   d. Full-load amperage and service factor.
   e. Number, make, and size of belts.

3. Test Data (Indicated and Actual Values):

   a. Total airflow rate in cfm (L/s).
   b. Total system static pressure in inches wg (Pa).
   c. Fan rpm.

d. Discharge static pressure in inches wg (Pa).

e. Suction static pressure in inches wg (Pa).

I. 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 (deg C).

d. Duct static pressure in inches wg (Pa).

e. Duct size in inches (mm).

f. Duct area in sq. ft. (sq. m).

g. Indicated air flow rate in cfm (L/s).

h. Indicated velocity in fpm (m/s).

i. Actual air flow rate in cfm (L/s).

j. Actual average velocity in fpm (m/s).

k. Barometric pressure in psig (Pa).

J. Air-Terminal-Device Reports:

1. Unit Data:

a. System and air-handling unit identification.

b. Location and zone.

c. Apparatus used for test.

d. Area served.

e. Make.

f. Number from system diagram.

g. Type and model number.

h. Size.

i. Effective area in sq. ft. (sq. m).

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm (L/s).

b. Air velocity in fpm (m/s).

c. Preliminary air flow rate as needed in cfm (L/s).

d. Preliminary velocity as needed in fpm (m/s).

e. Final air flow rate in cfm (L/s).

f. Final velocity in fpm (m/s).

g. Space temperature in deg F (deg C).

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

1. Unit Data:

a. Unit identification.

b. Location.

c. Service.

d. Make and size.

e. Model number and serial number.

f. Water flow rate in gpm (L/s).

g. Water pressure differential in feet of head or psig (kPa).

h. Required net positive suction head in feet of head or psig (kPa).

i. Pump rpm.

j. Impeller diameter in inches (mm).

k. Motor make and frame size.

l. Motor horsepower and rpm.

m. Voltage at each connection.

n. Amperage for each phase.

o. Full-load amperage and service factor.

p. Seal type.

2. Test Data (Indicated and Actual Values):

3. Static head in feet of head or psig (kPa).

4. Pump shutoff pressure in feet of head or psig (kPa).

5. Actual impeller size in inches (mm).

6. Full-open flow rate in gpm (L/s).

7. Full-open pressure in feet of head or psig (kPa).

8. Final discharge pressure in feet of head or psig (kPa).

9. Final suction pressure in feet of head or psig (kPa).

10. Final total pressure in feet of head or psig (kPa).

11. Final water flow rate in gpm (L/s).

12. Voltage at each connection.

13. Amperage for each phase.

L. Instrument Calibration Reports:

1. Report Data:

a. Instrument type and make.

b. Serial number.

c. Application.

d. Dates of use.

e. Dates of calibration.

26.20 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.

2. Check the following for each system:

a. Measure airflow of at least 10 percent of air outlets.

b. Measure water flow of at least 5 percent of terminals.

c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.

d. Verify that balancing devices are marked with final balance position.

e. Note deviations from the Contract Documents in the final report.

B. Final Inspection:

1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by the Engineer.
2. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of the Engineer.
3. The Engineer shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.
4. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
5. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

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

1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
2. If the second final inspection also fails, Owner may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

D. Prepare test and inspection reports.

26.21 ADDITIONAL TESTS

A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods : Perform additional TAB during near-peak summer and winter conditions.

XI. HVAC INSULATION

PART 27 - GENERAL

27.1 RELATED DOCUMENTS

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

27.2 SUMMARY

A. Section Includes:

1. Insulation Materials:

a. Calcium silicate.

b. Cellular glass.

c. Flexible elastomeric.

d. Mineral fiber.

e. Phenolic.

2. Fire-rated insulation systems.

3. Insulating cements.

4. Adhesives.

5. Mastics.

6. Lagging adhesives.

7. Sealants.

8. Factory-applied jackets.

9. Field-applied fabric-reinforcing mesh.

10. Field-applied cloths.

11. Field-applied jackets.

12. Tapes.

B. Related Sections:

1. Division 21 Section "Fire-Suppression Systems Insulation"

2. Division 22 Section "Plumbing Insulation"

3. Division 23 Section "Metal Ducts" for duct liners.

4. Division 33 Section "Underground Hydronic Energy Distribution" for loose-fill pipe insulation in underground piping outside the building.

5. Division 33 Section "Underground Steam and Condensate Distribution Piping" for loose-fill pipe insulation in underground piping outside the building.

27.3 SUBMITTALS

A. Product Data: For each type of product indicated. Include thermal conductivity, thickness, and jackets (both factory and field applied, if any).

B. LEED Submittal:

1. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.

C. Shop Drawings:

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
2. Detail insulation application at pipe expansion joints for each type of insulation.
3. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
4. Detail removable insulation at piping specialties, equipment connections, and access panels.
5. Detail application of field-applied jackets.
6. Detail application at linkages of control devices.
7. Detail field application for each equipment type.

D. Samples: For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use.

1. Sample Sizes:
    a. Preformed Pipe Insulation Materials: 300 mm long.
    b. Sheet Form Insulation Materials: 300 mm square.
    c. Jacket Materials for Pipe: 300 mm long.
    d. Sheet Jacket Materials: 300 mm square.
    e. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

E. Qualification Data: For qualified Installer.

F. Material Test Reports: from a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.

G. Field quality-control reports.

27.4 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. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per 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 and inspecting 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.

C. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by Architect. Use materials indicated for the completed Work.

1. Piping Mockups:

a. One 3m section of DN 50 straight pipe.

b. One each of a 90-degree threaded, welded, and flanged elbow.

c. One each of a threaded, welded, and flanged tee fitting.

d. One DN 50 or smaller valve, and one DN 65 or larger valve.

e. Four support hangers including hanger shield and insert.

f. One threaded strainer and one flanged strainer with removable portion of insulation.

g. One threaded reducer and one welded reducer.

h. One pressure temperature tap.

i. One mechanical coupling.

2. Ductwork Mockups:

a. One 3m section each of rectangular and round straight duct.

b. One each of a 90-degree mitered round and rectangular elbow, and one each of a 90-degree radius round and rectangular elbow.

c. One rectangular branch takeoff and one round branch takeoff from a rectangular duct. One round tee fitting.

d. One rectangular and round transition fitting.

e. Four support hangers for round and rectangular ductwork.

3. Equipment Mockups:

a. One chilled-water pump and one heating-hot-water pump.

b. One tank or vessel.

4. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.

5. Notify Engineer seven days in advance of dates and times when mockups will be constructed.

6. Obtain Architect's approval of mockups before starting insulation application.

7. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Engineer specifically approves such deviations in writing.

8. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.

9. Demolish and remove mockups when directed.

27.5 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.

27.6 COORDINATION

A. Coordinate size and location of supports, hangers, and insulation shields specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with piping Installer for piping insulation application duct Installer for duct insulation application, and equipment Installer for equipment insulation application. Before preparing piping and ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

27.7 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 28 - PRODUCTS

28.1 INSULATION MATERIALS

A. Comply with requirements in Part 3 schedule articles for where insulating materials shall be applied.

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

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

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

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

F. Calcium Silicate:

1. Products: As per approved Manufacturer’s list.
2. Preformed Pipe Sections: Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
3. Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
4. Prefabricated Fitting Covers: Comply with ASTM C 450 and ASTM C 585 for dimensions used in preforming insulation to cover valves, elbows, tees, and flanges.

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

1. Products: As per approved Manufacturer’s list:
2. Block Insulation: ASTM C 552, Type I.
3. Special-Shaped Insulation: ASTM C 552, Type III.
4. Board Insulation: ASTM C 552, Type IV.
5. Preformed Pipe Insulation with Factory-Applied jackets. Comply with ASTM C 552, Type II, Class 2.

H. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials and Type II for sheet materials.

1. Products: As per approved Manufacturer’s list.

I. 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 FSP jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: As per approved Manufacturer’s list.

J. High-Temperature, Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type V, without factory-applied jacket.

1. Products: As per approved Manufacturer’s list.

K. 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 FSP jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Products: As per approved Manufacturer's list.:

L. High-Temperature, Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type III, without factory-applied jacket.

1. Products: As per approved Manufacturer's list.

M. Mineral-Fiber, Preformed Pipe Insulation:

1. Products: Subject to compliance with requirements, as per approved Manufacturer's list.

N. Phenolic:

1. Products: As per approved Manufacturer's list.
2. Preformed pipe insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type III, Grade 1.
3. Block insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type II, Grade 1.
4. Factories fabricate shapes according to ASTM C 450 and ASTM C 585.
5. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.

28.2 FIRE-RATED INSULATION SYSTEMS

A. Fire-Rated Board: Structural-grade, press-molded, xonolite calcium silicate, fireproofing board suitable for operating temperatures up to 927 deg C. Comply with ASTM C 656, Type II, Grade 6 tested and certified to provide a 2-hour fire rating by a NRTL acceptable to authority having jurisdiction.

1. Products: As per approved Manufacturer's list:

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

1. Products: As per approved Manufacturer's list.

28.3 INSULATING CEMENTS

A. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.

1. Products: As per approved Manufacturer's list.

B. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449/C 449M.

1. Products: As per approved Manufacturer's list.

28.4 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. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 10 to 427 deg C.

1. Products: As per approved Manufacturer's list:
2. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

C. Cellular-Glass, Phenolic, Adhesive: Solvent-based resin adhesive, with a service temperature Products: As per approved Manufacturer's list.

1. 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).

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

1. Products: As per approved Manufacturer's list..
2. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

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

1. Products: As per approved Manufacturer's list.
2. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Products As per approved Manufacturer's list
4. 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).

28.5 MASTICS

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

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

1. Products: As per approved Manufacturer's list.
2. Water-Vapor Permeance: ASTM E 96, Procedure B, perm (0.009 metric perm) at.09-mm) dry film thickness.
3. Service Temperature Range: Minus 29 to plus 82 deg C.
4. Solids Content: ASTM D 1644, 59 percent by volume and 71 percent by weight.
5. Color: White.

C. Vapor-Barrier Mastic: As per approved Manufacturer's list.]:

1. Water-Vapor Permeance: ASTM F 1249, 0.03 metric perm at 0.9-mm dry film thickness.
2. Service Temperature Range: Minus 18 to plus 82 deg C.
3. Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight.
4. Color: White.

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

1. Products: Provide as per requirements from Approved Manufacturer list.

28.6 LAGGING ADHESIVES

A. Description: Comply with MIL-A-3316C Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.

1. Products: As per approved Manufacturer's list:
2. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over duct, equipment, and pipe insulation.
3. Service Temperature Range: Minus 46 deg C to plus 82 deg C.
4. Color: White

28.7 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass, Phenolic, products: Subject to compliance with requirements, provide as per approved Manufacturer's list.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Permanently flexible, elastomeric sealant.
4. Service Temperature Range: Minus 73 deg C to plus 149 deg C.
5. Color: White or gray
6. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

28.8 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. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.

28.9 FIELD-APPLIED FABRIC-REINFORCING MESH

A. Woven Glass-Fiber Fabric for Pipe Insulation: Approximately 68 g/sq. m with a thread count of 4 strands by 4 strands/sq. mm for covering pipe and pipe fittings.

1. Products: Subject to compliance with requirements, provide as per approved Manufacturer's list.

28.10 FIELD-APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 271 g/sq. m.

1. Products: Subject to compliance with requirements, provide as per approved Manufacturer's list.

28.11 FIELD-APPLIED JACKETS

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

B. Metal Jacket:

1. Products: Subject to compliance with requirements, provide as per approved Manufacturer's list
2. Aluminium Jacket: Comply with ASTM B 209 Alloy 3003, 3005, 3105 or 5005, Temper H-14.
    a. Factory cut and rolled to size.
    b. Finish and thickness are indicated in field-applied jacket schedules.
    c. Moisture Barrier for Indoor Applications0.025-mm- thick, heat-bonded polyethylene and kraft paper
    d. Moisture Barrier for Outdoor Applications: 0.075-mm- thick, heat-bonded polyethylene and kraft paper:
        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 covers.

8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

28.12 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, provide as per approved Manufacturer's list.
2. Width: 75 mm.
3. Thickness: 0.29 mm.
4. Adhesion: 1.0 N/mm in width.
5. Elongation: 2 percent.
6. Tensile Strength: 7.2 N/mm in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.

1. Products: Subject to compliance with requirements, provide as per approved Manufacturer's list:
2. Width: 75 mm.
3. Thickness: 0.16 mm.
4. Adhesion: 1.0 N/mm in width.
5. Elongation: 2 percent.
6. Tensile Strength: 7.2 N/mm in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

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

1. Products: Subject to compliance with requirements, provide as per approved Manufacturer's list
2. Width: 50 mm.
3. Thickness: 0.15 mm.
4. Adhesion: 0.7 N/mm in width.
5. Elongation: 500 percent.
6. Tensile Strength: 3.3 N/mm in width

PART 29 - EXECUTION

29.1 EXAMINATION

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

1. Verify that systems and equipment 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.

29.2 PREPARATION

A. Surface Preparation: Clean, dry and prepare surfaces to receive insulation. Remove materials that will adversely affect insulation application. Before insulating, apply a corrosion coating to insulated surfaces as follows:

1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 0.127 mm thick and an epoxy finish 0.127 mm thick if operating in a temperature range between 60 deg C and 149 deg C. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
2. Carbon Steel: Coat carbon steel operating at a service temperature between 0 deg C and 149 deg C with an zinc rich primer. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

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

29.3 GENERAL INSTALLATION REQUIREMENTS

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

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of equipment, duct system, and 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 75-mm- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 100 mm .

3. Overlap jacket longitudinal seams at least 38 mm. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 50 mm.

4. For below ambient services, apply vapor-barrier mastic over staples.

5. Cover joints and seams with tape as recommended by insulation material manufacturer to maintain vapor seal.

6. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct and pipe flanges and fittings.

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

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

O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 100 mm 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.

29.4 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 50 mm below top of roof flashing.
4. Seal jacket to roof flashing with flashing sealant.

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

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

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 50 mm.
4. Seal jacket to wall flashing with flashing sealant.

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

E. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions. 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 50 mm.

1. Comply with requirements in Division 07 Section "Penetration Firestopping" and fire-resistive joint sealers.

F. Insulation Installation at Floor Penetrations:

1. Duct: Install insulation continuously through floor penetrations that are not fire rated. 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 50 mm.
2. Pipe: Install insulation continuously through floor penetrations.
3. Seal penetrations through fire-rated assemblies. Comply with requirements in Division 07 Section "Penetration Firestopping."

29.5 EQUIPMENT, TANK, AND VESSEL INSULATION INSTALLATION

A. Mineral Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of tank and vessel surfaces.
2. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.
3. Protect exposed corners with secured corner angles.
4. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:

a. Do not weld anchor pins to ASME-labeled pressure vessels.

b. Select insulation hangers and adhesive those are compatible with service temperature and with substrate.

c. On tanks and vessels, maximum anchor-pin spacing is 75 mm from insulation end joints, and 400 mm o.c. in both directions.

d. Do not overcompress insulation during installation.

e. Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.

f. Impale insulation over anchor pins and attach speed washers.

g. 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.

5. Secure each layer of insulation with stainless-steel or aluminum bands. Select band material compatible with insulation materials.

6. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 150 mm from each end. Install wire or cable between two circumferential girdles 300 mm o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 1200 mm o.c. Use this network for securing insulation with tie wire or bands.

7. Stagger joints between insulation layers at least 75 mm.

8. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.

9. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.

10. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

B. Flexible Elastomeric Thermal Insulation Installation for Tanks and Vessels: Install insulation over entire surface of tanks and vessels.

1. Apply 100 percent coverage of adhesive to surface with manufacturer's recommended adhesive.

2. Seal longitudinal seams and end joints.

C. Insulation Installation on Pumps:

1. Fabricate metal boxes lined with insulation. Fit boxes around pumps and coincide box joints with splits in pump casings. Fabricate joints with outward bolted flanges. Bolt flanges on 150-mm centers, starting at corners. Install 10-mm- diameter fasteners with wing nuts. Alternatively, secure the box sections together using a latching mechanism.

2. Fabricate boxes from aluminum 1.0 mmFor below ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier.

29.6 GENERAL PIPE INSULATION INSTALLATION

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

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

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

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes, vessels, and equipment. 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 50 mm over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

29.7 CALCIUM SILICATE INSULATION INSTALLATION

A. Insulation Installation on Boiler Breechings and Generator Exhausts:

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

B. Insulation Installation on Straight Pipes and Tubes:

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

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.

4. Finish flange insulation same as pipe insulation.

D. 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 insulation sections of insulation are not available, install mitered sections of calcium silicate insulation. Secure insulation materials with wire or bands.

3. Finish fittings insulation same as pipe insulation.

E. Insulation Installation on Valves and Pipe Specialties:

1. Install mitered segments of calcium silicate insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

2. Install insulation to flanges as specified for flange insulation application.

3. Finish valve and specialty insulation same as pipe insulation.

29.8 CELLULAR-GLASS INSULATION INSTALLATION

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 150 mm o.c.

4. For insulation with factory-applied jackets 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.

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 25 mm, 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.

29.9 FLEXIBLE ELASTOMERIC INSULATION INSTALLATION

A. Seal longitudinal seams and end joints with manufacturers 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.

29.10 PHENOLIC INSULATION INSTALLATION

A. General Installation Requirements:

1. Secure single-layer insulation with stainless-steel bands at 300-mm intervals and tighten bands without deforming insulation materials.

2. Install 2-layer insulation with joints tightly butted and staggered at least 75 mm. Secure inner layer with 1.6-mm wire spaced at 300-mm intervals. Secure outer layer with stainless-steel bands at 300-mm 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 150 mm 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.

29.11 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 50-mm overlap at seams and joints.
2. Embed glass cloth between two 1.6-mm- thick coats of lagging adhesive.
3. Completely encapsulate insulation with coating, leaving no exposed insulation.

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

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

C. Where metal jackets are indicated, install with 50-mm overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 300 mm o.c. and at end joints.

29.12 FIRE-RATED INSULATION SYSTEM INSTALLATION

A. Where fire-rated insulation system is indicated, secure system to ducts and duct hangers and supports to maintain a continuous fire rating.

B. Insulate duct access panels and doors to achieve same fire rating as duct.

C. Install firestopping at penetrations through fire-rated assemblies. Fire-stop systems are specified in Division 07 Section "Penetration Firestopping."

29.13 FINISHES

A. Duct, Equipment, and Pipe Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Division 09 painting Sections.

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.

29.14 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(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.

2. Inspect field-insulated equipment, 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 number location(s) for each type of equipment defined in the "Equipment Insulation Schedule" Article. For large equipment, remove only a portion adequate to determine compliance.

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

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

29.15 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation:

1. Indoor, concealed supply and outdoor air.

2. Indoor, exposed supply and outdoor air.

3. Indoor, concealed return located in nonconditioned space.

4. Indoor, exposed return located in nonconditioned space.

5. Indoor, concealed, Type I, commercial, kitchen hood exhaust.

6. Indoor, exposed, Type I, commercial, kitchen hood exhaust.

7. Indoor, concealed exhaust between isolation damper and penetration of building exterior.

8. Indoor, exposed exhaust between isolation damper and penetration of building exterior.

9. Outdoor, concealed supply and return.

10. Outdoor, exposed supply and return.

B. Items Not Insulated:

1. Fibrous-glass ducts.

2. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.

3. Factory-insulated flexible ducts.

4. Factory-insulated plenums and casings.

5. Flexible connectors.

6. Vibration-control devices.

7. Factory-insulated access panels and doors.

29.16 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Concealed, round and flat-oval, supply-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

B. Concealed, round and flat-oval, return-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 25 mm thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

C. Concealed, round and flat-oval, outdoor-air duct insulation shall be[one of] the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 25 mm thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

D. Concealed, round and flat-oval, exhaust-air duct insulation shall be[one of] the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 25 mm thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

E. Concealed, rectangular, supply-air duct insulation shall be[one of] the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

F. Concealed, rectangular, return-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 25 mm thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

G. Concealed, rectangular, outdoor-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 25 mm thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

H. Concealed, rectangular, exhaust-air duct insulation between isolation damper and penetration of building exterior shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 25 mm thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

I. Concealed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated blanket or board; thickness as required to achieve 2-hour fire rating.

J. Concealed, supply-air plenum insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

K. Concealed, return-air plenum insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

L. Concealed, outdoor-air plenum insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

M. Concealed, exhaust-air plenum insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 25 mm thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

N. Exposed, round and flat-oval, supply-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

O. Exposed, round and flat-oval, return-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

P. Exposed, round and flat-oval, outdoor-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

Q. Exposed, round and flat-oval, exhaust-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.

2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.

3. Phenolic: 25 mm thick.

R. Exposed, rectangular, supply-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 40 mm thick.
2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.
3. Phenolic: 40 mm thick.

S. Exposed, rectangular, return-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.
2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.
3. Phenolic: 25 mm thick.

29.17 ABOVEGROUND, OUTDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Concealed, rectangular, return-air duct insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.
2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.
3. Phenolic: 25 mm thick.

B. Concealed, supply-air plenum insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.
2. Mineral-Fiber Board: 50 thick and 48-kg/cu. M nominal density.
3. Phenolic: 25 mm thick.

C. Concealed, return-air plenum insulation shall be one of the following:

1. Flexible Elastomeric: 25 mm thick.
2. Mineral-Fiber Board: 25 thick and 48-kg/cu. M nominal density.
3. Phenolic: 25 mm thick.

D. Chilled-water pump insulation shall be[one of] the following:

1. Cellular Glass: 75 mm thick.
2. Phenolic: 50 mm thick.

E. Chilled-water expansion/compression tank insulation shall be[one of] the following:

1. Cellular Glass: 50 mm thick.
2. Flexible Elastomeric: 25 mmthick.
3. Mineral-Fiber Board25 mmthick and48-kg/cu. mnominal density.
4. Phenolic: 25 mm thick.

F. Heating-hot-water expansion/compression tank/generatot exhaust:

1. Calcium Silicate: 2 inches (50 mm
2. Cellular Glass: 38 mmthick.
3. Mineral-Fiber Board: 48-kg/cu. M nominal density.

29.18 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.

29.19 INDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water below 60 Deg F (16 Deg C):

1. All Pipe Sizes: Insulation shall be[one of] the following:

a. Flexible Elastomeric: 19 mm thick.

b. Mineral-Fiber, Preformed Pipe Insulation, Type I: 25 mm

c. Phenolic: 25 mm thick.

B. Chilled Water and Brine, 57 Deg F (14 Deg C) and below:

1. DN80 and Smaller: Insulation shall be one of the following:

a. Cellular Glass: 50 mm thick.

b. Mineral-Fiber, Preformed Pipe, 50 mm thick.

c. Phenolic: 38 mm thick.

2. DN100 to DN300: Insulation shall be one of the following:

a. Cellular Glass: 50 mm thick.

b. Mineral-Fiber, Preformed Pipe 50 mm thick.

c. Phenolic: 38 mm thick.

3. DN 350 and Larger: Insulation shall be one of the following:

a. Cellular Glass: 75 mm thick.

b. Mineral-Fiber, Preformed Pipe 75 mm thick.

c. Phenolic: 50 mmthick.

C. Refrigerant Suction and Hot-Gas Piping:

1. All Pipe Sizes: Insulation shall be one of the following:

a. Flexible Elastomeric: 25 mm thick.

b. Mineral-Fiber, Preformed Pipe Insulation, 25 mm thick.

c. Phenolic: 25 mm thick.

D. Heat-Recovery Piping:

1. All Pipe Sizes: Insulation shall be one of the following:

a. Cellular Glass: 38 mm thick.

b. Flexible Elastomeric: 25 mm thick.

c. Mineral-Fiber, Preformed Pipe Insulation, Type I: 25 mm thick.

d. Phenolic: 25 mm thick.

29.20 OUTDOOR, UNDERGROUND PIPING INSULATION SCHEDULE

A. Loose-fill insulation, for belowground piping, is specified in Division 33 piping distribution Sections.

B. Chilled Water, All Sizes: Cellular glass, 50 mm thick.

C. Condenser-Water Supply and Return, All Sizes: Cellular glass, 50 mm thick.

1. Calcium Silicate: [3 inches (75 mm)] <Insert thickness> thick.

29.21 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. Ducts and Plenums, Concealed:

1. None.

C. Ducts and Plenums, Exposed:

1. Aluminum, Corrugated 0.51 mm thick.

D. Equipment, Concealed:

1. None.

E. Equipment, Exposed,

1. Aluminum, Corrugated 0.51 mm

F. Piping, Concealed:

1. None.

G. Piping, Exposed:

1. Aluminum, Corrugated 0.51 mm thick.

29.22 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Ducts and Plenums, Concealed:

1. None.

D. Ducts and Plenums, Exposed,

1. Aluminum, Corrugated 0.61 mm thick.

E. Equipment, Concealed:

1. None.

F. Equipment, Exposed,

1. Painted Aluminum, Corrugated 0.61 mm thick.

G. Piping, Concealed:

1. None.

H. Piping, Exposed:

1. Aluminum, Corrugated 0.61 mm thick.

29.23 UNDERGROUND, FIELD-INSTALLED INSULATION JACKET

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

XII. COMMISSIONING OF HVAC

PART 30 - GENERAL

30.1 RELATED DOCUMENTS

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

30.2 SUMMARY

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

B. Related Sections:

1. Division 01 Section "General Commissioning Requirements" for general commissioning process requirements.

30.3 DEFINITIONS

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

B. CxA: Commissioning Authority.

C. HVAC&R: Heating, Ventilating, Air Conditioning, and Refrigeration.

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

30.4 CONTRACTOR'S RESPONSIBILITIES

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

B. Attend construction phase controls coordination meeting.

C. Attend testing, adjusting, and balancing review and coordination meeting.

D. Participate in HVAC&R systems, assemblies, equipment, and component maintenance orientation and inspection as directed by the CxA.

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

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

30.5 CXA'S RESPONSIBILITIES

A. Verify and approve project-specific construction checklists and commissioning process test procedures for all actual HVAC&R systems, assemblies, equipment, and components to be installed as part of the construction contract.

B. Direct commissioning testing.

C. Verify testing, adjusting, and balancing of Work are complete.

D. Verify and approve test data, inspection reports, and certificates in Systems Manual, provided in the commissioning documentation.

30.6 COMMISSIONING DOCUMENTATION

A. Provide the following information to the CxA:

1. Plan for delivery and review of submittals, systems manuals, and other documents and reports.

2. Identification of installed systems, assemblies, equipment, and components including design changes that occurred during the construction phase.

3. Process and schedule for completing construction checklists and manufacturer's prestart and startup checklists for HVAC&R systems, assemblies, equipment, and components to be verified and tested.
4. Certificate of completion certifying that installation, prestart checks, and startup procedures have been completed.
5. Certificate of readiness certifying that HVAC&R systems, subsystems, equipment, and associated controls are ready for testing.
6. Test and inspection reports and certificates.
7. Corrective action documents.
8. Verification of testing, adjusting, and balancing reports.

30.7 SUBMITTALS

A. Certificates of readiness.

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

PART 31 - EXECUTION

31.1 TESTING PREPARATION

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

B. Certify that HVAC&R 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 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. Set 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.

31.2 TESTING AND BALANCING VERIFICATION

A. Prior to performance of testing and balancing Work, provide copies of reports, sample forms, checklists, and certificates to the CxA.

B. Notify the CxA at least 10 days in advance of testing and balancing Work, and provide access for the CxA to witness testing and balancing Work.

C. Provide technicians, instrumentation, and tools to verify testing and balancing of HVAC&R systems at the direction of the CxA.

1. The CxA will notify Contractor 10 days in advance of the date of field verification. Notice will not include data points to be verified.
2. The testing and balancing 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 than 10 percent. Failure of more than 10 percent of selected items shall result in rejection of final testing, adjusting, and balancing report. For sound pressure readings, a deviation of 3 dB shall result in rejection of final testing. Variations in background noise must be considered.
4. Remedy the deficiency and notify the CxA so verification of failed portions can be performed.

31.3 GENERAL TESTING REQUIREMENTS

A. Provide technicians, instrumentation, and tools to perform commissioning test at the direction of the CxA.

B. Scope of HVAC&R testing shall include entire HVAC&R installation, from central equipment for heat generation and refrigeration through distribution systems to each conditioned space. Testing shall include measuring capacities and effectiveness of operational and control functions.

C. 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.

D. The TAB Contractor along with the Contractor, and HVAC&R Instrumentation and Control Subcontractor shall prepare detailed testing plans, procedures, and checklists for HVAC&R systems, subsystems, and equipment.

E. Tests will be performed using design conditions whenever possible.

F. 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.

G. The CxA may direct that set points be altered when simulating conditions is not practical.

H. 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.

I. If tests cannot be completed because of a deficiency outside the scope of the HVAC&R system, document the deficiency and report it to the Owner. After deficiencies are resolved, reschedule tests.

J. If the testing plan indicates specific seasonal testing, complete appropriate initial performance tests and documentation and schedule seasonal tests.

31.4 HVAC & R SYSTEMS, SUBSYSTEMS, AND EQUIPMENT TESTING PROCEDURES

A. HVAC&R Instrumentation and Control System Testing: Field testing plans and testing requirements are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls." Assist the CxA with preparation of testing plans.

B. Pipe system cleaning, flushing, hydrostatic tests and chemical treatment requirements are specified in Division 23 piping Sections. MEP 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.

C. Refrigeration System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of chillers, cooling towers, refrigerant compressors and condensers, and other refrigeration systems. The CxA shall determine the sequence of testing and testing procedures for each equipment item and pipe section to be tested.

D. HVAC&R Distribution System Testing: Provide technicians, instrumentation, tools, and equipment to test performance of air, and hydronic distribution systems; special exhaust; and other distribution systems, including HVAC&R terminal equipment and unitary equipment.

E. Vibration and Sound Tests: Provide technicians, instrumentation, tools, and equipment to test performance of vibration isolation and seismic controls

XIII. INSTRUMENTATION AND CONTROLS FOR HVAC

PART 32 - GENERAL

32.1 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Section 23 09 13.23 - Sensors and Transmitters

1. Airflow stations
2. Flow meters
3. Flow switches
4. Hydronic temp sensor wells and sockets
5. Liquid differential pressure sensors with copper tubing
6. Pipe line pressure sensors

B. Section 23 09 13.33 - Control Valves

1. Control valves

C. Section 23 09 13.43 - Control Dampers

1. Automated Dampers

D. Section 23 70 00 - Central HVAC Equipment

1. AHU, heating, and ventilating unit controls

E. Section 23 80 00 - Decentralized HVAC Equipment

1. Terminal unit controls

32.2 PRODUCTS INSTALLED BUT NOT FURNISHED UNDER THIS SECTION

A. None

32.3 PRODUCTS NOT FURNISHED OR INSTALLED UNDER BUT INTEGRATED WITH THE WORK OF THIS SECTION

A. Section - General

1. Coordination Meeting

B. Section 26 29 00 - Low-Voltage Controllers

1. Variable frequency drives

C. Section 23 64 16 - Central Cooling Equipment

1. Chiller controls

D. Section - M-bus/Bacnet

1. BTU Metering
2. Energy meters
3. Gas consumption meters

E. Section - Modbus

1. Generator
2. UPS
3. PMU Metering
4. Water Treatment Package PLC
5. ABULOX Dosing system

F. Section - Hardwired

1. MDB/EMDB
2. Fire Alarm Panel
3. Access Control Panel / CCTV
4. Fire hydrant pump sets
5. Sprinkler & Firefighting pump sets
6. Zone control valves
7. Domestic & Fire water tank level status
8. Booster & tertiary pumps for water
9. Gas leak detection Panel

G. Section - DALI

1. Lighting Control System

32.4 RELATED SECTIONS

A. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.

B. The following sections constitute related work:

1. Section 01 30 00 - Administrative Requirements
2. Section 01 60 00 - Product Requirements
3. Section 01 80 00 - Performance Requirements
4. Section 01 90 00 - Life Cycle Activities
5. Section 23 05 00 - Common Work Results for HVAC
6. Section 23 30 00 - HVAC Air Distribution

32.5 DESCRIPTION

A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and a web-based operator interface.

B. System software shall be based on a server/thin client architecture, designed around the open standards of web technology. The control system server shall be accessed using a Web browser over the control system network, the owner's local area network, and (at the owner's discretion) over the Internet.
The intent of the thin-client architecture is to provide operators complete access to the control system via a Web browser. No special software other than a web browser shall be required to access graphics, point displays, and trends, configure trends, configure points and controllers, or to download programming into the controllers.

C. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control module I/O points, schedules, setpoints, trends and alarms specified in 23 09 93 – "Sequence of Operations for HVAC Controls" shall be BACnet objects.

32.6 APPROVED CONTROL SYSTEM MANUFACTURERS

A. Please refer approved manufacturers list

1. Control systems shall comply with the terms of this specification.

2. The Contractor shall use only operator workstation software, controller software, custom application programming language, and controllers from the corresponding manufacturer and product line unless Owner approves use of multiple manufacturers.
3. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

32.7 QUALITY ASSURANCE

A. Installer and Manufacturer Qualifications

1. Installer shall have an established working relationship with Control System Manufacturer.
2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.
3. Installer shall submit his organization chart with escalation level matrix. The chart should include the relevant experience & qualification of each personnel.
4. Installer shall upon request furnish the resume of his project team members/present for client interview.

32.8 CODES AND STANDARDS

A. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with the current editions in effect 30 days prior to the receipt of bids of the following codes:

1. National Electric Code (NEC)
2. ANSI/ASHRAE Standard 135, BACnet - A Data Communication Protocol for Building Automation and Control Systems

32.9 SYSTEM PERFORMANCE

A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).

1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 sec.
2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 sec. and shall automatically refresh every 15 sec.
3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 15 sec.
6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.

8. Multiple Alarm Annunciations. Each workstation on the network shall receive alarms within 5 sec of other workstations.
9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.
10. Control Stability and Accuracy. Control loops shall maintain measured variable at setpoint within tolerances listed in Table 2.

B. Table-1 Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5°C (±1°F)
Ducted Air	±0.5°C (±1°F)
Outside Air	±1.0°C (±2°F)
Dew Point	±1.5°C (±3°F)
Water Temperature	±0.5°C (±1°F)
Delta-T	±0.15° (±0.25°F)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO2)	±50 ppm

1. Note 1: Accuracy applies to 10%–100% of scale
2. Note 2: For both absolute and differential pressure
3. Note 3: Not including utility-supplied meters

C. Table 2 Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0–1.5 kPa (0–6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0°C (±2.0°F)	
Duct Temperature	±1.5°C (±3°F)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	MPa (1–150 psi) 0–12.5 kPa (0–50 in. w.g.) differential

32.10 SUBMITTALS

A. Product Data and Shop Drawings: Meet requirements of Section 01 30 00 on Shop Drawings, Product Data, and Samples. In addition, the contractor shall provide shop drawings or other submittals on hardware, software, and equipment to be installed or provided. No work may begin on any segment of this project until submittals have been approved for conformity with design intent. Provide drawings as AutoCAD 2006 (or newer) compatible files on magnetic or optical disk (file format: .DWG, .DXF, .VSD, or comparable) and three 11" x 17" prints of each drawing. When manufacturer's cutsheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawing shall clearly reference the specification and/or drawing that the submittal is to cover. General catalogs shall not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Contractor of responsibility to supply sufficient quantities to complete work. Submittals shall be provided within 12 weeks of contract award. Submittals shall include:

1. DDC System Hardware

a. A complete bill of materials to be used indicating quantity, manufacturer, model number, country of origin and relevant technical data of equipment to be used.

b. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:

1) Direct digital controllers (controller panels)
2) I/O expansion modules
3) Add-on modules
4) Transducers and transmitters
5) Sensors (including accuracy data)
6) Actuators
7) Valves
8) Relays and switches
9) Control panels
10) Power supplies
11) Batteries
12) Operator interface equipment
13) Wiring

c. Wiring diagrams and layouts for each control panel. Show termination numbers.

d. Schematic diagrams for all field sensors and controllers. Provide floor plans of all sensor locations and control hardware. Riser diagrams showing control network layout, communication protocol, and wire types.

e. Clearly highlight the model number used for the project in the datasheets.

2. Central System Hardware and Software

a. A complete bill of material of equipment used indicating quantity, manufacturer, model number, and relevant technical.

b. Manufacturer’s description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:

1) Central Processing Unit (CPU) or web server
2) Monitors
3) Keyboards
4) Power supplies
5) Battery backups
6) Interface equipment between CPU or server and control panels
7) Operating System software
8) Operator interface software
9) Color graphic software
10) Third-party software

c. Schematic diagrams for all control, communication, and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers’ model numbers and functions. Show interface wiring to control system.

d. Network riser diagrams of wiring between central control unit and control panels.

3. Controlled Systems

a. Riser diagrams showing control network layout, communication protocol, and wire types.

b. A schematic diagram of each controlled system. The schematics shall have all control points labeled with point names shown or listed. The schematics shall graphically show the location of all control elements in the system.

c. A schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.

d. An instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.

e. A system overview list which includes all the equipment connected to BMS as specified in IO schedule with quantity & control type specified as control/monitor or both.

f. A mounting, wiring, and routing plan-view drawing. The design shall take into account HVAC, electrical, and other systems’ design and elevation requirements. The drawing shall show the specific location of all concrete pads and bases and any special wall bracing for panels to accommodate this work.

g. A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.

h. A point list for each control system. List I/O points and software points specified in Section 23 09 93. Indicate alarmed and trended points.

4. Quantities of items submitted shall be reviewed but are the responsibility of the Contractor.

5. Description of process, report formats, and checklists to be used in Section 23 09 23 Article 3.16 (Control System Demonstration and Acceptance).
6. BACnet Protocol Implementation Conformance Statement (PICS) for each submitted type of controller and operator interface.

B. Schedules

1. Within one month of contract award, provide a schedule of the work indicating the following:
   a. Intended sequence of work items
   b. Start date of each work item
   c. Duration of each work item
   d. Planned delivery dates for ordered material and equipment and expected lead times
   e. Milestones indicating possible restraints on work by other trades or situations
   f. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.
2. Project Record Documents. Upon completion of installation, submit three copies of record (as-built) documents of the documents shall be submitted for approval prior to final completion and shall include:
   a. Project Record Drawings. As-built versions of submittal shop drawings provided as AutoCAD 2006 (or newer) compatible files on magnetic or optical media (file format: .DWG, .DXF, .VSD, or comparable) and as 11" x 17" prints.
   b. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 23 09 23 Article 3.16 (Control System Demonstration and Acceptance).
   c. Operation and Maintenance (O&M) Manual.
   d. As-built versions of submittal product data.
   e. As-built DDC panel wiring drawings.
   f. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
   g. Operator’s manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
   h. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
   i. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
   j. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be viewed using furnished programming tools.
   k. Graphic files, programs, and database on magnetic or optical media.

l. List of recommended spare parts with part numbers and suppliers.

m. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.

n. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.

o. Licenses, guarantees, and warranty documents for equipment and systems.

p. All original software/driver CDs/DVDs shipped with each product.

q. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

r. Training Materials: Provide course outline and materials for each class at least six weeks before first class. Training shall be furnished via instructor-led sessions, computer-based training, or web-based training. Engineer will modify course outlines and materials if necessary to meet Owner's needs. Engineer will review and approve course outlines and materials at least three weeks before first class.

32.11 WARRANTY

1. Warrant work as follows:

a. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request.

b. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.

c. If the engineer determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, the engineer will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.

d. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve the contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.

e. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

32.12 OWNERSHIP OF PROPRIETARY MATERIAL

1. Project-specific software and documentation shall become Owner's property. This includes, but is not limited to:

   a. Graphics

   b. Record drawings

   c. Database

   d. Application programming code

   e. Documentation

32.13 DEFINITIONS

Term	Definition
BACnet Interoperability Building Blocks (BIBB)	BIBBS- Define a set of BACnet services to provide a specific function. BIBBS are combined to build the BACnet functional requirements for a device in a specification.
PIC - Protocol Implementation Conformance statement	PICS is a standard way of describing the BACnet functionality of a specific solution in a kind of table format and contains information about-BACnet services supported , BACnet standard objects supported ,data link layer options etc.
BACnet/BACnet Standard	BACnet communication requirements as defined by the latest version of ASHRAE/ANSI 135 and approved addenda.
Control Systems Server	A computer(s) that maintain(s) the systems configuration and programming database & responds to client machine(s)
Controller	Intelligent stand-alone control device. Controller is a generic reference to building controllers, custom application controllers, and application specific controllers.
Direct Digital Control	Microprocessor-based control including Analog/Digital conversion and programmable logic.
Gateway	Bi-directional protocol translator connecting control systems that use different communication protocols.
Local Area Network	Computer or control system communications network limited to local building or campus.
Master-Slave/Token Passing	Data link protocol as defined by the BACnet standard.
Point-to-Point	Serial communication as defined in the BACnet standard.
Primary Controlling LAN	High speed, peer-to-peer controller LAN connecting BCs and optionally AACs and ASCs. Refer to System Architecture below.
Router	A device that connects two or more networks at the network layer.
Wiring	Raceway, fittings, wire, boxes and related items.

PART 33 - PRODUCTS

33.1 MATERIALS

A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.

33.2 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135, BACnet.

B. Install new wiring and network devices as required to provide a complete and workable control network.

C. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

D. Internetwork operator interface and value passing shall be transparent to internetwork architecture.

1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.

2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Section 23 09 93. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

E. Workstations, Building Control Panels, and Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight saving and standard time as applicable.

F. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

33.3 OPERATOR INTERFACE

A. The Operator Workstation or server shall conform to the BACnet Operator Workstation (B-OWS) or BACnet Advanced Workstation (B-AWS) device profile as specified in ASHRAE/ANSI 135 BACnet Annex L.

B. Should be BTL tested , certified & listed.

C. Operator Interface. Web server shall reside on high-speed network with building controllers. Each standard browser connected to server shall be able to access all system information.

D. Communication. Web server or workstation and controllers shall communicate using BACnet protocol. Web server or workstation and control network backbone shall communicate using ISO

8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135, BACnet Annex J.

E. Hardware. Each workstation or web server shall consist of the following:

1. Computer. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The following hardware requirements also apply:

a. The hard disk shall have sufficient memory to store:

1) All required operator workstation software.

2) A DDC database at least twice the size of the delivered system database.

3) One year of trend data based on the points specified to be trended at their specified trend intervals.

b. Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.

c. Minimum hardware configuration shall include the following:

1) Dual or Quad Core Processor

2) 6 GB RAM

3) 500 GB hard disk providing data at 3.0 Gb/sec

4) 16x DVD-RW drive

5) Serial, parallel, and network communication ports and cables as required for proper DDC system operation

F. System Software.

1. Operating System. Web server or workstation shall have an industry-standard professional-grade operating system. Operating system shall meet or exceed the DDC System manufacturers minimum requirements for their software. Typically, acceptable systems include Microsoft Windows7, Microsoft Vista, Microsoft Windows XP Pro, Windows Server 2003 or 2008, Red Hat Enterprise Linux, or Ubuntu Desktop 10.04.

Cyber security. The vendor shall provide anti-virus software with free virus definition updates for the duration of the warranty. Antivirus software shall automatically scan the computer BIOS and all files opened, created, copied, and/or received for viruses. The vendor shall include directions for updating virus definition files upon expiration of warranty within the record documentation

2. System Graphics. The operator interface software shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.

a. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.

b. Animation. Graphics shall be able to animate by displaying different image files for changed object status.

c. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.

d. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, or GIF. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in (such as HTML and JavaScript) or shall only require widely available no-cost plug-ins (such as Active-X and Adobe Flash).

3. Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system that uses the mouse to create and modify graphics that are saved in the same formats as are used for system graphics.

4. Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.

5. System Applications. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on standard IBM-compatible PCs with no limit on the number of copies that can be installed under the system license.

a. Automatic System Database Configuration. Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.

b. Manual Controller Memory Download. Operators shall be able to download memory from the system database to each controller.

c. System Configuration. The workstation software shall provide a method of configuring the system. This shall allow for future system changes or additions by users under proper password protection. Operators shall be able to configure the system.

d. On-Line Help. Provide a context-sensitive, on-line help system to assist the operator in operating and editing the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext.

33.4

a. Security. Each operator shall be required to log on to the system with user name and password in order to view, edit, add, or delete data.

1) Operator Access. The user name and password combination shall define accessible viewing, editing, adding, and deleting privileges for that operator. Users with system administrator rights shall be able to create new users and edit the privileges of all existing users. System Administrators shall also be able to vary and deny each operator's privileges based on the geographic location, such as the ability to edit operating parameters in Building A, to view but not edit parameters in Building B, and to not even see equipment in Building C.

2) Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. This auto logoff time shall be user adjustable.

3) Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

4) Unlimited number of users shall be supported who are allowed to access the device

5) The BMS should allow distinguishing between different rights of different users

6) Shall support 255 user levels(user categories)

7) Shall allow for 100 concurrent web browsers at minimum.

8) For web browser access the BMS software shall support Secure Socket Layer(SSL) communitation(HTTPS) with web browser.

b. System Diagnostics. The system shall automatically monitor the operation of all building management panels and controllers. The failure of any device shall be annunciated to the operator.

c. Alarm Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as specified in Section 23 09 93 (Sequences of Operation). Alarms shall be BACnet alarm objects and shall use BACnet alarm services.

d. Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying on acronyms.

e. Alarm Reactions. Operator shall be able to configure (by object) what, if any actions are to be taken during an alarm. As a minimum, the workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.

f. Alarm and Event log. Operators shall be able to view all system alarms and changes of state from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and delete alarms, and archive closed alarms to the workstation or web server hard disk.

g. Trend Logs. The operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as specified in Section 23 09 93 (Sequences of Operation). Trends shall be BACnet trend objects.

h. Object and Property Status and Control. Provide a method for the operator to view, and edit if applicable, the status of any object or property in the system. The status shall be available by menu, on graphics, or through custom programs.

i. Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.

j. Standard Reports. Furnish the following standard system reports:

1) Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.

2) Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.

3) Logs. System shall log the following to a database or text file and shall retain data for an adjustable period:

a) Alarm History.

b) Trend Data. Operator shall be able to select trends to be logged.

c) Operator Activity. At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm acknowledgment and deletion. System shall date and time stamp logged activity.

2. Energy Reports. System shall include an easily configured energy reporting tool that provides the capabilities described in this section.

a. The energy reporting tool shall be accessible through the same user interface (Web browser or operator workstation software) as is used to manage the BAS.

b. The energy reporting tool shall be preconfigured by the Contractor to gather and store energy demand and consumption data from each energy source that provides metered data to the BAS. Meter data shall be stored at 5 minute intervals unless otherwise specified in the Sequence of Operation provided in section 23 09 93. This data shall be maintained in an industry standard SQL database for a period of not less than five years.

c. The energy reporting tool shall allow the operator to select an energy source and a time period of interest (day, week, month, year, or date range) and shall provide options to view the data in a table, line graph, bar graph, or pie chart. The tool shall also allow the operator to select two or more data sources and display a comparison of the energy used over this period in any of the listed graph formats, or to total the energy used by the selected sources and display that data in the supported formats.

d. The energy reporting tool shall allow the operator to select and energy source and two time periods of interest (day, week, month, year, or date range) and display a graph that compares the energy use over the two time periods in any of the graph formats listed in the previous paragraph. The tool shall also allow the operator to select multiple energy sources and display a graph that compares the total energy used by these sources over the two time periods.

e. The energy reporting tool shall allow the operator to easily generate the previously described graphs "on the fly," and shall provide an option to store the report format so the operator can select that format to regenerate the graph at a future date. The tool shall also allow the user to schedule these reports to run on a recurring basis using relative time periods, such as automatically generating a consumption report on the first Monday of each month showing consumption over the previous month. Automatically generated reports shall be archived on the server in a common industry format such as Adobe PDF or Microsoft Excel with copies e-mailed to a user editable list of recipients.

f. The energy reporting tool shall be capable of collecting and displaying data from the following types of meters:

1) Electricity
2) Gas
3) Oil
4) Steam
5) Chilled Water
6) Potable Water
7) Heating and cooling degree days. (May be calculated from sensor data rather than metered.)

g. The user shall have the option of using Kw (Kwh) or Btu/hr (Btu) as the units for demand and consumption reports. Multiples of these units (MWH, kBtu, etc.) shall be used as appropriate. All selected sources shall be automatically converted to the selected units. The user shall similarly have the option of entering facility area and occupancy hours and creating reports that are normalized on an area basis, an annual use basis, or an occupied hour basis.

h. The user shall have the option of entering benchmark data for an individual facility or a group of facilities.

i. The user shall have the option of displaying any or all of the following data on any chart, line, or bar graph generated by the energy reporting tool:

1) Low/High/Average value of the metered value being displayed.
2) Heating and/or Cooling Degree Days for the time period(s) being displayed.
3) The Environmental Index for the facilities and time periods being displayed.

j. Environmental Index. System shall monitor all occupied zones and compile an index that provides a numerical indication of the environmental comfort within the zone. As a minimum, this indication shall be based upon the deviation of the zone temperature from the heating or cooling setpoint. If humidity is being measured within the zone then the environmental index shall be adjusted to reflect a lower comfort level for high or low humidity levels. Similarly, if carbon dioxide levels are being measured as an indication of ventilation effectiveness then the environmental index shall be adjusted to indicate degraded comfort at high carbon dioxide levels. Other adjustments may be made to the environmental index based upon additional measurements. The system shall maintain a trend of the environmental index for each zone in the trend log. The system shall also compute an average comfort index for every building included in this contract and maintain trend logs of these building environmental indices. Similarly, the system shall compute the percentage of occupied time that comfortable conditions were maintained within the zones. Through the UI the user shall be able to add a weighting factor to adjust the contribution of each zone to the average index based upon the floor area of the zone, importance of the zone, or other static criteria.

k. Custom Reports. Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface.

l. Additional Drivers for various protocols shall be supported & regulated by licensing method - The workstation software shall support the following drivers : ModbusTCP/IP , MbusTCP/IP,BacnetTCP/IP,OPC , SNMP, EIB IP , LON IP ,OBIX , FIDELIO system driver for hotel booking , MSSQL , DB2 , MYSQL , ORACLE as minimum.

m. Tenant Billing - Tenant billing module shall be supported & regulated by licensing method which should support configurable rate structures , automatic generation of reports & invoices , multiple currencies , tax & surcharge ,searchable invoice histories, report function(daily) detailing override periods & cost breakdown , suitable for billing utilities like electricity ,gas , oil , steam , chilled water. The license should be upgradable & expandable for future.

B. Workstation Application Editors. Each PC or browser workstation shall support editing of all system applications. The applications shall be downloaded and executed at one or more of the controller panels.

1. Controller. Provide a full-screen editor for each type of application that shall allow the operator to view and change the configuration, name, control parameters, and set points for all controllers.

2. Scheduling. An editor for the scheduling application shall be provided at each workstation. Provide a method of selecting the desired schedule and schedule type. Exception schedules and holidays shall be shown clearly on the calendar. The start and stop times for each object shall be adjustable from this interface.

3. Custom Application Programming. Provide the tools to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:

a. Language. Language shall be graphically based and shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks.

b. Programming Environment. Tool shall provide a full-screen, cursor-and-mouse-driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.

c. Independent Program Modules. Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.

d. Debugging and Simulation. Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step's time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.

e. Conditional Statements. Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.

f. Mathematical Functions. Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.

g. Variables. Operator shall be able to use variable values in program conditional statements and mathematical functions.

1) Time Variables. Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.

2) System Variables. Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.

4. Portable Operator's Terminal. Provide all necessary software to configure an IBM-compatible laptop computer for use as a Portable Operator's Terminal. Operator shall be able to connect configured Terminal to the system network or directly to each controller for programming, setting up, and troubleshooting.

33.5 CONTROLLER SOFTWARE

A. Furnish the following applications for building and energy management. All software application shall reside and operate in the system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

B. System Security. See Paragraph 2.3.E.5 (Security) and Paragraph 2.3.E.14.c.iii (Operator Activity).

C. Scheduling. Provide the capability to execute control functions according to a user created or edited schedule. Each schedule shall provide the following schedule options as a minimum:

1. Weekly Schedule. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).
2. Exception Schedules. Provide the ability for the operator to designate any day of the year as an exception schedule. Exception schedules may be defined up to a year in advance. Once an exception schedule has executed, the system shall discard and replace the exception schedule with the standard schedule for that day of the week.
3. Holiday Schedules. Provide the capability for the operator to define up to 24 special or holiday schedules. These schedules will be repeated each year. The operator shall be able to define the length of each holiday period.

D. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.

E. Binary Alarms. Each binary object shall have the capability to be configured to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.

F. Analog Alarms. Each analog object shall have both high and low alarm limits. The operator shall be able to enable or disable these alarms.

G. Alarm Reporting. The operator shall be able to determine the action to be taken in the event of an alarm. An alarm shall be able to start programs, print, be logged in the event log, generate custom messages, and display on graphics.

H. Remote Communication. System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.

I. Demand Limiting.

1. The demand-limiting program shall monitor building power consumption from a building power meter (provided by others) which generates pulse signals or a BACnet communications interface. An acceptable alternative is for the system to monitor a watt transducer or current transformer attached to the building feeder lines.
2. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand as specified in Section 23 09 93 (Sequences of Operation). When demand drops below adjustable levels, system shall restore loads as specified.

J. Maintenance Management. The system shall be capable of generating maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in 23 09 93 (Sequences of Operation).

K. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified in Section 23 09 93 (Sequences of Operation).

L. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs. The calculation interval, PID gains, and other tuning parameters shall be adjustable by a user with the correct security level.

M. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.

N. Energy Calculations.

1. The system shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.

2. The system shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.

O. Anti-Short Cycling. All binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

P. On and Off Control with Differential. Provide an algorithm that allows a binary output to be cycled based on a controlled variable and a setpoint. The algorithm shall be direct-acting or reverse-acting.

Q. Runtime Totalization. Provide software to totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified in Section 23 09 93 (Sequence of Operations).

33.6 CONTROLLERS

A. General. Provide an adequate number of Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance specified in Section 23 09 23 Article 1.9 (System Performance). Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors.

B. BACnet.

1. Building Controllers (BCs). Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L, and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.

2. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.

3. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.

4. Smart Sensors (SSs). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.

5. BACnet Communication.

a. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.

b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.

c. Each AAC shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.

d. Each ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.

e. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.

f. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using ARCNET or MS/TP Data Link/Physical layer protocol.

C. Communication

1. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator’s Terminal. Connection shall be extended to space temperature sensor ports were shown on drawings.

2. Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.

3. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.

4. Stand-Alone Operation. Each piece of equipment specified in Section 23 09 93 shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.

D. Environment. Controller hardware shall be suitable for anticipated ambient conditions.

1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29°C to 60°C (-20°F to 140°F).

2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

E. Keypad. Provide a local keypad and display for each BC and AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized use. If the manufacturer does not normally provide a keypad and display for each BC and AAC, provide the software and any interface cabling needed to use a laptop computer as a Portable Operator’s Terminal for the system.

F. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.

G. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.

H. Memory.

1. Controller memory shall support operating system, database, and programming requirements.

2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.

3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

I. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

J. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

33.7 INPUT AND OUTPUT INTERFACE

A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.

B. Protection. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground shall cause no damage to the controller. All input and output points shall be protected from voltage up to 24 V of any duration, such that contact with this voltage will cause no controller damage.

C. Binary Inputs. Binary inputs shall allow the monitoring of ON/OFF signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.

D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall also accumulate up to 10 pulses per second.

E. Analog Inputs. Analog inputs shall monitor low-voltage (0–10 Vdc), current (4–20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

F. Binary Outputs. Binary outputs shall provide for ON/OFF operation or a pulsed low-voltage signal for pulse width modulation control. Binary outputs on Building Controllers shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

G. Analog Outputs. Analog outputs shall 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 properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.

H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

I. System Object Capacity. The system size shall be expandable to at least twice the number of input/ output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system

33.8 POWER SUPPLIES AND LINE FILTERING

A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.

    a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.

    b. Line voltage units shall be UL recognized and CSA listed.

2. Power Line Filtering.

3. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:

    a. Dielectric strength of 1000 V minimum

    b. Response time of 10 nanoseconds or less

    c. Transverse mode noise attenuation of 65 dB or greater

    d. Common mode noise attenuation of 150 dB or greater at 40–100 Hz

33.9 AUXILIARY CONTROL DEVICES

A. Motorized Control Dampers, unless otherwise specified elsewhere, shall be as follow.

1. Type. Control dampers shall be the parallel or opposed-blade type as specified below or as scheduled on drawings.

    a. Outdoor and return air mixing dampers and face-and-bypass dampers shall be parallel-blade and shall direct airstreams toward each other.

    b. Other modulating dampers shall be opposed-blade.

    c. Two-position shutoff dampers shall be parallel- or opposed-blade with blade and side seals.

2. Frame. Damper frames shall be 2.38 mm (13 gauge) galvanized steel channel or 3.175 mm (⅛ in.) extruded aluminum with reinforced corner bracing.

3. Blades. Damper blades shall not exceed 20 cm (8 in.) in width or 125 cm (48 in.) in length. Blades shall be suitable for medium velocity (10 m/s [2000 fpm]) performance. Blades shall be not less than 1.5875 mm (16 gauge).

4. Shaft Bearings. Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze, or better.

5. Seals. Blade edges and frame top and bottom shall have replaceable seals of butyl rubber or neoprene. Side seals shall be spring-loaded stainless steel. Blade seals shall leak no more than 50 L/s·m2(10 cfm per ft2) at 1000 Pa (4 in. w.g.) differential pressure. Blades shall be airfoil type suitable for wide-open face velocity of 7.5 m/s (1500 fpm).

6. Sections. Individual damper sections shall not exceed 125 cm × 150 cm (48 in. × 60 in.). Each section shall have at least one damper actuator.

7. Modulating dampers shall provide a linear flow characteristic where possible.

8. Linkages. Dampers shall have exposed linkages.

B. Electric Damper and Valve Actuators.

1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator’s rotation.

2. Spring-return Mechanism. Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).

3. Signal and Range. Proportional actuators shall accept a 0–10 Vdc or a 0–20 mA control signal and shall have a 2–10 Vdc or 4–20 mA operating range. (Floating motor actuators may be substituted for proportional actuators in terminal unit applications as described in paragraph 2.6H.)

4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.

5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 7 N·m (60 in.-lb) torque capacity shall have a manual crank.

C. Control Valves.

1. Control valves shall be two-way or three-way type for two-position or modulating service as shown.

2. Close-off (differential) Pressure Rating: Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:

a. Water Valves:

1) Two-way: 150% of total system (pump) head.

2) Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.

b. Steam Valves: 150% of operating (inlet) pressure.

3. Water Valves.

a. Body and trim style and materials shall be in accordance with manufacturer's recommendations for design conditions and service shown, with equal percentage ports for modulating service.

b. Sizing Criteria:

1) Two-position service: Line size.

2) Two-way modulating service: Pressure drop shall be equal to twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 5 psi, whichever is greater.

3) Three-way modulating service: Pressure drop equal to twice the pressure drop through the coil exchanger (load), 35 kPa (5 psi) maximum.

4) Valves ½ in. through 2 in. shall be bronze body or cast brass ANSI Class 250, spring-loaded, PTFE packing, quick opening for two-position service. Two-way valves to have replaceable composition disc or stainless steel ball.

5) Valves 2½ in. and larger shall be cast iron ANSI Class 125 with guided plug and PTFE packing.

c. Water valves shall fail normally open or closed, as scheduled on plans, or as follows:

1) Water zone valves—normally open preferred.

2) Heating coils in air handlers—normally open.

3) Chilled water control valves—normally closed.

4) Other applications—as scheduled or as required by sequences of operation.

4. Steam Valves.

a. Body and trim materials shall be in accordance with manufacturer's recommendations for design conditions and service with linear ports for modulating service.

b. Sizing Criteria:

1) Two-position service: pressure drop 10% to 20% of inlet psig.

2) Modulating service: 100 kPa (15 psig) or less; pressure drop 80% of inlet psig.

3) Modulating service: 101 to 350 kPa (16 to 50 psig); pressure drop 50% of inlet psig.

4) Modulating service: over 350 kPa (50 psig); pressure drop as scheduled on plans.

D. Binary Temperature Devices.

1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C–30°C (55°F–85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.

2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment,

13°C–30°C (55°F–85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.

3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

E. Temperature Sensors.

1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.
2. Duct Sensors. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m2(10 ft2) of duct cross-section.
3. Immersion Sensors. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.
4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown.
5. Differential Sensors. Provide matched sensors for differential temperature measurement.

F. Humidity Sensors.

1. Duct and room sensors shall have a sensing range of 20%–80%.
2. Duct sensors shall have a sampling chamber.
3. Outdoor air humidity sensors shall have a sensing range of 20%–95% RH and shall be suitable for ambient conditions of -40°C–75°C (-40°F–170°F).
4. Humidity sensors shall not drift more than 1% of full scale annually.

G. Flow Switches. Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service) as shown. Switches shall be UL listed, SPDT snap-acting, and pilot duty rated (125 VA minimum).

1. Paddle switches shall have adjustable sensitivity and NEMA 1 enclosure unless otherwise specified.
2. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

H. Relays.

1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have dust cover and LED “energized” indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
2. Time Delay Relays. Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

I. Override Timers.

1. Unless implemented in control software, override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration required by application. Provide 0–6 hour calibrated dial unless otherwise specified. Flush mount timer on local control panel face or where shown.

J. Current Transmitters.

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

K. Current Transformers.

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

L. Voltage Transmitters.

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

M. Voltage Transformers.

1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 4°C–55°C (40°F–130°F) and shall provide ±0.5% accuracy at 24 Vac and 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

N. Power Monitors.

1. Selectable rate pulse output for kWh reading, 4–20 mA output for kW reading, N.O. alarm contact, and ability to operate with 5.0 amp current inputs or 0–0.33 volt inputs.
2. 1.0% full-scale true RMS power accuracy, +0.5 Hz, voltage input range 120–600 V, and auto range select.
3. Under voltage/phase monitor circuitry.
4. NEMA 1 enclosure.

5. Current transformers having a 0.5% FS accuracy, 600 VAC isolation voltage with 0–0.33 V output. If 0–5 A current transformers are provided, a three-phase disconnect/shorting switch assembly is required.

O. Hydronic Flowmeters

1. Insertion-Type Turbine Meter

a. Dual counter-rotating axial turbine elements, each with its own rotational sensing system, and an averaging circuit to reduce measurement errors due to swirl and flow profile distortion. Single turbine for piping 2 inches and smaller. Flow sensing turbine rotors shall be non-metallic and not impaired by magnetic drag.

b. Insertion type complete with 'hot-tap' isolation valves to enable sensor removal without water supply system shutdown.

c. Sensing method shall be impedance sensing (non magnetic and non photoelectric)

d. Volumetric accuracy

1) ± 0.5% of reading at calibrated velocity

2) ± 1% of reading from 3 to 30 ft/s (10:1 range)

3) ± 2% of reading from 0.4 to 20 ft/s (50:1 range)

e. Each sensor shall be individually calibrated and tagged accordingly against the manufacturer's primary standards which must be accurate to within 0.1% of flow rate and traceable to the National Institute of Standards and Technology (NIST).

f. Maximum operating pressure of 400 psi and maximum operating temperature of 200°F continuous (220°F peak).

g. All wetted metal parts shall be constructed of 316 stainless steel.

h. Analog outputs shall consist of non interactive zero and span adjustments, a DC linearly of 0.1% of span, voltage output of 0-10 Vdc, and current output of 4-20 mA.

2. Magnetic Flow-Tube Type Flowmeter

a. Sensor shall be a magnetic flowmeter, which utilizes Faraday's Law to measure volumetric fluid flow through a pipe. The flowmeter shall consist of two elements, the sensor and the electronics. The sensor shall generate a measuring signal proportional to the flow velocity in the pipe. The electronics shall convert this EMF into a standard current output.

b. Electronic replacement shall not affect meter accuracy (electronic units are not matched with specific sensors).

c. Four-wire, externally powered, magnetic type flow transmitter with adjustable span and zero, integrally mounted to flow tube. Output signal shall be a digital pulse proportional to the flow rate (to provide maximum accuracy and to handle abrupt changes in flow). Standard 4-20 mA or 0-10 Vdc outputs may be used provided accuracy is as specified.

d. Flow Tube:

1) ANSI class 150 psig steel

2) ANSI flanges

3) Protected with PTFE, PFA, or ETFE liner rated for 245°F minimum fluid temperature

e. Electrode and grounding material

1) 316L Stainless steel or Hastelloy C

2) Electrodes shall be fused to ceramic liner and not require o-rings.

f. Electrical Enclosure: NEMA 4, 7

g. Approvals:

1) UL or CSA

2) NSF Drinking Water approval for domestic water applications

h. Performance

1) Accuracy shall be ±0.5% of actual reading from 3 to 30 ft/s flow velocities, and 0.015 ft/s from 0.04 to 3 ft/s.

2) Stability: 0.1% of rate over six months.

3) Meter repeatability shall be ±0.1% of rate at velocities > 3 ft/s.

P. Magnetic Insertion-Type Flowmeter

1. Magnetic Faraday point velocity measuring device.
2. Insertion type complete with hot-tap isolation valves to enable sensor removal without water supply system shutdown.
3. 4-20 mA transmitter proportional to flow or velocity.
4. Accuracy: larger of 1% of reading and 0.2 ft/s.
5. Flow range: 0.2 to 20 ft/s, bidirectional.
6. Each sensor shall be individually calibrated and tagged accordingly against the manufacturer's primary standards which must be accurate to within 0.1% of flow rate and traceable to the National Institute of Standards and Technology (NIST).

Q. Vortex Shedding Flowmeter

1. Output: 4-20 mA, 0-10 Vdc, 0-5 Vdc.
2. Maximum Fluid Temperature: 800ºF (427 °C).
3. Wetted Parts: Stainless Steel.
4. Housing: NEMA 4X.
5. Turndown: 25:1 minimum.
6. Accuracy: 0.5% of calibrated span for liquids, 1% of calibrated span for steam and gases.
7. Body: Wafer style or ANSI flanged to match piping specification.

R. Transit-Time Ultrasonic Flowmeter

1. Clamp-On transit-time ultrasonic flowmeter
2. Wide-Beam transducer technology
3. 4-20 mA transmitter proportional to flow or velocity.
4. Accuracy: 0.5% of reading in range 1 to 30 ft/s, 0.001 ft/s sensitivity.

S. Thermal Energy Meters

1. Matched RTD, solid state, or thermistor temperature sensors with a differential temperature accuracy of ±0.15°F.
2. Flow meter : See "Hydronic Flowmeters" section.
3. Unit accuracy of ±1% factory calibrated, traceable to NIST with certification.
4. NEMA 1 enclosure.
5. Panel mounted display.
6. UL listed.
7. Isolated 4–20 ma signals for energy rate and supply and return temperatures and flow.

T. Current Switches.

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

U. Pressure Transducers.

1. Transducers shall have linear output signal and field-adjustable zero and span.
2. Transducer sensing elements shall withstand continuous operating conditions of positive or negative pressure 50% greater than calibrated span without damage.
3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4–20 mA output, suitable mounting provisions, and block and bleed valves.
4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure shall be 2000 kPa (300 psi.) Transducer shall have 4–20 mA output, suitable mounting provisions, and 5-valve manifold.

V. Differential Pressure Switches. Differential pressure switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

W. Pressure-Electric (PE) Switches.

1. Shall be metal or neoprene diaphragm actuated, operating pressure rated for 0–175 kPa (0–25 psig), with calibrated scale minimum setpoint range of 14–125 kPa (2–18 psig) minimum, UL listed.
2. Provide one- or two-stage switch action (SPDT, DPST, or DPDT) as required by application Electrically rated for pilot duty service (125 VA minimum) and/or for motor control.
3. Switches shall be open type (panel-mounted) or enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.
4. Each pneumatic signal line to PE switches shall have permanent indicating gauge.

X. Occupancy Sensors. Occupancy sensors shall utilize Passive Infrared (PIR) and/or Microphonic Passive technology to detect the presence of people within a room. Sensors shall be mounted as indicated on the approved drawings. The sensor output shall be accessible by any lighting and/or HVAC controller in the system. Occupancy sensors shall be capable of being powered from the lighting or HVAC control panel, as shown on the drawings. Occupancy sensor delay shall be software adjustable through the user interface and shall not require manual adjustment at the sensor.

Y. Local Control Panels.

1. All indoor control cabinets shall be fully enclosed NEMA 1 construction with (hinged door) key-lock latch and removable subpanels. A single key shall be common to all field panels and subpanels.
2. Interconnections between internal and face-mounted devices shall be prewired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL listed for 600 volt service, individually identified per control/ interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
3. Provide ON/OFF power switch with overcurrent protection for control power sources to each local panel.

33.10 WIRING AND RACEWAYS

A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

33.11 FIBER OPTIC CABLE SYSTEM

A. Optical Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.

B. Connectors. Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

PART 34 - EXECUTION

34.1 EXAMINATION

A. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.

B. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by—and at the expense of—this contractor.

34.2 PROTECTION

A. The contractor shall protect all work and material from damage by his/her work or employees and shall be liable for all damage thus caused.

B. The contractor shall be responsible for his/her work and equipment until finally inspected, tested, and accepted. The contractor shall protect any material that is not immediately installed. The contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

34.3 COORDINATION

A. Site

1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition without extra charge.
2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

B. Submittals. See Section 23 09 23 Article 1.10 (Submittals).

C. Test and Balance.

1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.
2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
3. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.
4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

D. Life Safety.

1. Duct smoke detectors required for air handler shutdown are provided under Division 28. Interlock smoke detectors to air handlers for shutdown as specified in Section 23 09 93 (Sequences of Operation).

2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23. Interlock smoke dampers to air handlers as specified in Section 23 09 93 (Sequences of Operation).

3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 23. Fire and smoke damper control is provided under Division 28.

E. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:

1. All communication media and equipment shall be provided as specified in Section 23 09 23 Article 2.2 (Communication).

2. Each supplier of a controls product is responsible for the configuration, programming, start up, and testing of that product to meet the sequences of operation described in Section 23 09 93.

3. The contractor shall coordinate and resolve any incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.

4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.

5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

34.4 GENERAL WORKMANSHIP

A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.

B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

C. Install equipment in readily accessible locations as defined by Chapter 1 Article 100 Part A of the National Electrical Code (NEC).

D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

E. All equipment, installation, and wiring shall comply with industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

34.5 FIELD QUALITY CONTROL

A. All work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Section 23 09 23 Article 1.8 (Codes and Standards).

B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.

C. Contractor shall have work inspection by local and/or state authorities having jurisdiction over the work.

34.6 WIRING

A. All control and interlock wiring shall comply with national and local electrical codes, and Division 26 of this specification, Where the requirements of this section differ from Division 26, the requirements of this section shall take precedence.

B. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 26 requirements.

C. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.

D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended application.

E. All wiring in mechanical, electrical, or service rooms – or where subject to mechanical damage – shall be installed in raceway at levels below 3 m (10ft).

F. Do not install Class 2 wiring in raceways containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).

G. Do not install wiring in raceway containing tubing.

H. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.

I. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.

J. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.

K. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

L. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.

M. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

N. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.

O. Size of raceway and size and type of wire type shall be the responsibility of the contractor in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.

P. Include one pull string in each raceway 2.5 cm (1 in.) or larger.

Q. Use color-coded conductors throughout with conductors of different colors.

R. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

S. Conceal all raceways except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g. steam pipes or flues).

T. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

U. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.

V. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of vertical raceways.

W. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

X. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.

Y. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

34.7 COMMUNICATION WIRING

A. The contractor shall adhere to the items listed in the "Wiring" article in Part 3 of the specification.

B. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling

C. Do not install communication wiring in raceways and enclosures containing Class 1 or other Class 2 wiring.

D. Maximum pulling, tension, and bend radius for the cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.

E. Contractor shall verify the integrity of the entire network following cable installation. Use appropriate test measures for each particular cable.

F. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to manufacturer's instructions.

G. All runs of communication wiring shall be unspliced length when that length is commercially available.

H. All communication wiring shall be labeled to indicate origination and destination data.

I. All communication wiring shall be labeled to indicate origination and destination data.

J. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

K. BACnet MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:

1. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)
2. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.
3. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
4. An MS/TP EIA-485 network shall have no T connections.

34.8 FIBER OPTIC CABLE

A. Maximum pulling tensions as specified by the cable manufacturer shall not be exceeded during installation. Post-installation residual cable tension shall be within cable manufacturer's specifications.

B. All cabling and associated components shall be installed in accordance with manufacturers' instructions. Minimum cable and unjacketed fiber bend radii, as specified by cable manufacturer, shall be maintained.

34.9 INSTALLATION OF SENSORS

A. Install sensors in accordance with the manufacturer's recommendations.

B. Mount sensors rigidly and adequately for environment within which the sensor operates.

C. Room temperature sensors shall be installed on concealed junction boxes properly supported by wall framing.

D. All wires attached to sensors shall be sealed in their raceways or in the wall to stop air transmitted from other areas from affecting sensor readings.

E. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.

F. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m^2(1 ft^2) of coil area.

G. Do not install temperature sensors within the vapor plume of a humidifier. If installing a sensor downstream of a humidifier, install it at least 3 m (10 ft) downstream.

H. All pipe-mounted temperature sensors shall be installed in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

I. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.

J. Differential Air Static Pressure.

1. Supply Duct Static Pressure. Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the height-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.

2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.

3. Building Static Pressure. Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.

4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.

5. All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.

6. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shut-off valves installed before the tee.

K. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.

L. Install humidity sensors for duct mounted humidifiers at least 3 m (10 ft) downstream of the humidifier. Do not install filters between the humidifier and the sensor.

34.10 FLOW SWITCH INSTALLATION

A. Use correct paddle for pipe diameter.

B. Adjust flow switch according to manufacturer's instructions.

34.11 ACTUATORS

A. General. Mount and link control damper actuators according to manufacturer's instructions.

1. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.
2. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
3. Provide all mounting hardware and linkages for actuator installation.

B. Electric/Electronic

1. Dampers: Actuators shall be direct mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° travel available for tightening the damper seal. Actuators shall be mounted following manufacturer's recommendations.
2. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

C. Pneumatic Actuators.

1. Size pneumatic damper actuator to operate the related control damper(s) with sufficient reserve power to provide smooth modulating action or two-position action. Actuator also shall be sized for proper speed of response at the velocity and pressure conditions to which the control damper is subject.
2. Pneumatic damper actuators shall produce sufficient torque to close off against the maximum system pressures encountered. Size the pneumatic damper actuator to close off against the fan shutoff pressure, as a minimum.
3. Where two or more pneumatic damper actuators are installed for interrelated operation in unison, such as dampers used for mixing, provide the dampers with a positive pilot positioner. The positive pilot positioner shall be directly mounted to the pneumatic damper actuator and have pressure gauges for supply input and output pressures.
4. The total damper area operated by an actuator shall not exceed 80% of the manufacturer's maximum area rating. Provide at least one actuator for each damper section. Each damper actuator shall not power more than 2 m2(20 ft2) of damper.
5. Use line shafting or shaft couplings (jackshafting) in lieu of blade-to-blade linkages or shaft coupling when driving axially aligned damper sections.

34.12 WARNING LABELS

A. Permanent warning labels shall be affixed to all equipment that can be automatically started by the control system.

1. Labels shall use white lettering (12-point type or larger) on a red background.

2. Warning labels shall read as follows.

a. Caution

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

B. Permanent warning labels shall be affixed to all motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.

1. Labels shall use white lettering (12-point type or larger) on a red background.

2. Warning labels shall read as follows.

a. C A U T I O N

1) This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

34.13 IDENTIFICATION OF HARDWARE AND WIRING

A. All wiring and cabling, including that within factory-fabricated panels shall be labeled at each end within 5 cm (2 in.) of termination with control system address or termination number.

B. All pneumatic tubing shall be labeled at each end within 5 cm (2 in.) of termination with a descriptive identifier.

C. Permanently label or code each point of field terminal strips to show the instrument or item served.

D. Identify control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.

E. Identify all other control components with permanent labels. All plug-in components shall be labeled such that label removal of the component does not remove the label.

F. Identify room sensors related to terminal boxes or valves with nameplates.

G. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

H. Identifiers shall match record documents.

34.14 CONTROLLERS

A. Provide a separate controller for each AHU or other HVAC system. A DDC controller may control more than one system provided that all points associated with the system are assigned to the same DDC controller. Points used for control loop reset, such as outside air or space temperature, are exempt from this requirement.

B. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all of the hardware points listed in Section 23 09 93 (Sequences of Operation).

C. Provide 10% spare IO of each type in DDC panel for future expansion.

D. The B-BC controller should have 32 bit processor ,400MHz speed ,128MB DDR-2 RAM ,1GB Flash memory. It should support minimum 600 points through IO panelbus modules or through software integration. It should be able to support modbus-RS484 , Mbus ,Lon , Bacnet MS/TP devices integration in addition to IO points.

34.15 PROGRAMMING

A. Provide sufficient internal memory for the specified sequences of operation and trend logging.

B. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See Section 23 09 93 (Sequences of Operation). If character limitations or space restrictions make it advisable to shorten the name, the abbreviations given in Appendix B to Section 23 09 93 may be used. Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, "Zone Temp 1" for Zone 1, "Zone Temp 2" for Zone 2.

C. Software Programming.

1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor. Embed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. Use the appropriate technique based on the following programming types:

a. Text-based:

1) Must provide actions for all possible situations

2) Must be modular and structured

3) Must be commented

b. Graphic-based:

1) Must provide actions for all possible situations

2) Must be documented

c. Parameter-based:

1) Must provide actions for all possible situations

2) Must be documented.

D. Operator Interface.

1. Standard Graphics. Provide graphics for all mechanical systems and floor plans of the building. This includes each chilled water system, hot water system, chiller, boiler, air handler, and all terminal equipment. Point information on the graphic displays shall dynamically update. Show on each graphic all input and output points for the system. Also show relevant calculated points such as setpoints. As a minimum, show on each equipment graphic the input and output points and relevant calculated points as indicated on the applicable Points List in Section 23 09 93.

2. The contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all operator interface software and its functions as described in this section. This includes any operating system software, the operator interface database, and any third-party software installation and integration required for successful operation of the operator interface.

34.16 CONTROL SYSTEM CHECKOUT AND TESTING

A. Startup Testing. All testing listed in this article shall be performed by the contractor and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the owner's representative is notified of the system demonstration.

1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
2. The contractor must raise an inspection request 2 days prior to planned inspection date to ensure that client/consultant representative is available to witness the inspection.
3. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
4. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
5. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
6. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
7. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops.
8. The contractor must attend all the comments mentioned in the inspection report & raise the inspection request again & till the report is approved.
9. Alarms and Interlocks:
    a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
    b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
    c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action

34.17 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

A. Demonstration.

1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in Part 3 of this specification. The engineer will be present to observe and review these tests. The engineer shall be notified at least 10 days in advance of the start of the testing procedures.
3. The demonstration process shall follow that approved in Part 1, "Submittals." The approved checklists and forms shall be completed for all systems as part of the demonstration.
4. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm,

seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.

5. As each control input and output is checked, a log shall be completed showing the date, technician's initials, and any corrective action taken or needed.
6. Demonstrate compliance with Part 1, "System Performance."
7. Demonstrate compliance with sequences of operation through all modes of operation.
8. Demonstrate complete operation of operator interface.
9. Additionally, the following items shall be demonstrated:
    a. DDC loop response. The contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop's response to a change in set point, which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 10 seconds to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled variable values. Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the Contractor.
    b. Demand limiting. The contractor shall supply a trend data output showing the action of the demand limiting algorithm. The data shall document the action on a minute-by-minute basis over at least a 30-minute period. Included in the trend shall be building kW, demand limiting set point, and the status of sheddable equipment outputs.
    c. Optimum start/stop. The contractor shall supply a trend data output showing the capability of the algorithm. The change-of-value or change-of-state trends shall include the output status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
    d. Interface to the building fire alarm system.
    e. Operational logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the architect/engineer. These logs shall cover three 48-hour periods and have a sample frequency of not more than 10 minutes. The logs shall be provided in both printed and disk formats.
10. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

B. Acceptance.

1. All tests described in this specification shall have been performed to the satisfaction of both the engineer and owner prior to the acceptance of the control system as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the contractor may be exempt from the completion requirements if stated as such in writing by the engineer. Such tests shall then be performed as part of the warranty.
2. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in Part 1, "Submittals."

34.18 CLEANING

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.

B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.

C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

34.19 TRAINING

A. Provide training for a designated staff of Owner’s representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.

B. Training shall enable students to accomplish the following objectives.

1. Day-to-day Operators:
   a. Proficiently operate the system
   b. Understand control system architecture and configuration
   c. Understand DDC system components
   d. Understand system operation, including DDC system control and optimizing routines (algorithms)
   e. Operate the workstation and peripherals
   f. Log on and off the system
   g. Access graphics, point reports, and logs
   h. Adjust and change system set points, time schedules, and holiday schedules
   i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
   j. Understand system drawings and Operation and Maintenance manual
   k. Understand the job layout and location of control components
   l. Access data from DDC controllers and ASCs
   m. Operate portable operator's terminals
2. Advanced Operators:
   a. Make and change graphics on the workstation
   b. Create, delete, and modify alarms, including annunciation and routing of these
   c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
   d. Create, delete, and modify reports
   e. Add, remove, and modify system's physical points
   f. Create, modify, and delete programming
   g. Add panels when required
   h. Add operator interface stations
   i. Create, delete, and modify system displays, both graphical and others
   j. Perform DDC system field checkout procedures

k. Perform DDC controller unit operation and maintenance procedures

l. Perform workstation and peripheral operation and maintenance procedures

m. Perform DDC system diagnostic procedures

n. Configure hardware including PC boards, switches, communication, and I/O points

o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware

p. Adjust, calibrate, and replace system components

3. System Managers/Administrators:

a. Maintain software and prepare backups

b. Interface with job-specific, third-party operator software

c. Add new users and understand password security procedures

C. Organize the training into sessions or modules for the three levels of operators listed above. (Day-to-Day Operators, Advanced Operators, System Managers and Administrators). Students will receive one or more of the training packages, depending on knowledge level required.

D. Provide course outline and materials according to the "Submittals" article in Part 1 of this specification. Provide one copy of training material per student.

E. The instructor(s) shall be factory-trained and experienced in presenting this material.

F. Classroom training shall be done using a network of working controllers representative of installed hardware.

34.20 SEQUENCES OF OPERATION

A. See Section 23, Appendix A (Sequences of Operation, With Points Lists).

34.21 CONTROL VALVE INSTALLATION

A. Valve submittals shall be coordinated for type, quantity, size, and piping configuration to ensure compatibility with pipe design.

B. Slip-stem control valves shall be installed so that the stem position is not more than 60 degrees from the vertical up position. Ball type control valves shall be installed with the stem in the horizontal position.

C. Valves shall be installed in accordance with the manufacturer's recommendations.

D. Control valves shall be installed so that they are accessible and serviceable and so that actuators may be serviced and removed without interference from structure or other pipes and/or equipment.

E. Isolation valves shall be installed so that the control valve body may be serviced without draining the supply/return side piping system. Unions shall be installed at all connections to screw-type control valves.

F. Provide tags for all control valves indicating service and number. Tags shall be brass, 1.5 inch in diameter, with ¼ inch high letters. Securely fasten with chain and hook. Match identification numbers as shown on approved controls shop drawings.

34.22 CONTROL DAMPER INSTALLATION

A. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.

B. Duct openings shall be free of any obstruction or irregularities that might interfere with blade or linkage rotation or actuator mounting. Duct openings shall measure ¼ in. larger than damper dimensions and shall be square, straight, and level.

C. Individual damper sections, as well as entire multiple section assemblies, must be completely square and free from racking, twisting, or bending. Measure diagonally from upper corners to opposite lower corners of each damper section. Both dimensions must be within 0.3 cm (1/8 in.) of each other.

D. Follow the manufacturer's instructions for field installation of control dampers. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.

E. Install extended shaft or jackshaft according to manufacturer's instructions. (Typically, a sticker on the damper face shows recommended extended shaft location. Attach shaft on labeled side of damper to that blade.)

F. Damper blades, axles, and linkage must operate without binding. Before system operation, cycle damper after installation to ensure proper operation. On multiple section assemblies, all sections must open and close simultaneously.

G. Provide a visible and accessible indication of damper position on the drive shaft end.

H. Support ductwork in area of damper when required to prevent sagging due to damper weight.

I. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

34.23 SMOKE DAMPER INSTALLATION

A. The contractor shall coordinate all smoke and smoke/fire damper installation, wiring, and checkout to ensure that these dampers function properly and that they respond to the proper fire alarm system general, zone, and/or detector trips. The contractor shall immediately report any discrepancies to the engineer no less than two weeks prior to inspection by the code authority having jurisdiction.

B. Provide complete submittal data to controls system subcontractor for coordination of duct smoke detector interface to HVAC systems.

34.24 DUCT SMOKE DETECTION

A. Submit data for coordination of duct smoke detector interface to HVAC systems as required in Part 1, "Submittals."

B. This Contractor shall provide a dry-contact alarm output in the same room as the HVAC equipment to be controlled.

34.25 CONTROLS COMMUNICATION PROTOCOL

A. General. The electronic controls packaged with this equipment shall communicate with the building direct digital control (DDC) system. The DDC system shall communicate with these controls to read the information and change the control setpoints as shown in the points list, sequences of operation, and control schematics. The information to be communicated between the DDC system and these controls shall be in the standard object format as defined in ANSI/ASHRAE Standard 135 (BACnet). Controllers shall communicate with other BACnet objects on the internetwork using the Read (Execute) Property service as defined in Clause 15.5 of Standard 135.

B. Distributed Processing. The controller shall be capable of stand-alone operation and shall continue to provide control functions if the network connection is lost.

C. I/O Capacity. The controller shall contain sufficient I/ O capacity to control the target system.

D. The Controller shall have a physical connection for a laptop computer or a portable operator's tool.

E. Environment. The hardware shall be suitable for the anticipated ambient conditions.

1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at 40°C to 60°C (40°F to 140°F).
2. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
3. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field removable, modular terminal strips or to a termination card connected by a ribbon cable.
4. Memory. The Controller shall maintain all BIOS and programming information in the event of a power loss for at least 30 days.
5. Power. Controller shall be able to operate at 90% to 110% of nominal voltage rating.
6. Transformer. Power supply for the Controller must be rated at minimum of 125% of ASC power consumption and shall be fused or current limiting type.

34.26 START-UP AND CHECKOUT PROCEDURES

A. Start up, check out, and test all hardware and software and verify communication between all components.

1. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
2. Verify that all analog and binary input/output points read properly.
3. Verify alarms and interlocks.
4. Verify Operation of Integrated System.

XIV. PRESSURE INDEPENDENT CONTROL VALVE

PART 36 - PRODUCTS

36.1 AUTOMATIC CONTROL VALVES

A. Valves shall have stainless-steel stems and stuffing boxes with extended necks to clear the piping insulation. Valves bodies shall meet ASME B16.34 or ASME B16.15 pressure and temperature class ratings based on the design operating temperature and 150 percent of the system design operating pressure. Unless otherwise specified or shown, valve leakage shall meet FCI 70-2 Class IV leakage rating (0.01percent of valve Kv). Unless otherwise specified or shown, valves shall be two-way pressure independent globe-style bodies. Unless otherwise specified:

1. Bodies for valves 2 inches and smaller shall be brass or bronze, with union ends
2. Bodies for valves 2 to 3 inches shall be of brass, bronze or iron.
3. Bodies of valves 2½ Inches and larger shall be provided with flanged-end connections
4. Valve and actuator combination shall be normally open or normally closed as shown

36.2 TWO-WAY PRESSURE INDEPENDENT GLOBE VALVES

A. Two-way modulating valves used for liquids. The valve shall be two-way globe style with integrated differential pressure control regulator. Where indicated modulating proportional valve application shall utilize controller or actuator to match required control signal to complement controlled coil heat transfer characteristic for linear control, the valve shall:

1. Provide integrated pressure regulator; regulator to control pressure across control valve orifice
2. Provide regulator incorporating EPDM diaphragm, stainless steel spring and pressure control disc. Pressure control seat shall be brass construction with vulcanized EPDM
3. Provide counterbalance of supply pipe pressure to return pipe pressure across diaphragm to prevent diaphragm damage when control valve is closed
4. Provide user adjustable maximum flow within valve control range; Adjustment method shall indicate percentage of valve flow range and utilize spring locked method of adjustment
5. Regulate internal control valve differential pressure to provide 100% control valve authority
6. Shall have linear flow characteristic provide back seated globe design to allow service of packing under pressure without leakage
7. Provide entering to leaving (P1-P3) pressure control across valve ½" in size from 2.3PSI - 60PSI
8. Provide entering to leaving (P1-P3) pressure control across valves ½" -1¼" in size from 5PSI 60PSI
9. Provide entering to leaving (P1 -P3) pressure control across valves 1½" -10" in size from 4PSI 60PSI
10. Provide union connections
11. Utilize stainless steel internal trim with brass globe seat m. utilize threaded actuator connection
12. Flow requirements shall be sized to provide nominal body selection no more than one size smaller to corresponding nominal pipe connection:

a. ½" bodies shall be utilized for ½" pipe and may be utilized for ¾" pipe connection and flow

b. less than 5 GPM

c. ¾" bodies may be utilized for ¾" pipe and may be applied to 1" pipe connection with flow

d. less than 7.5 GPM

e. 1" bodies may be utilized for 1” pipe and may be applied to 1¼" pipe connection with flow

f. less than 12 GPM

g. 1¼" bodies may be utilized for 1¼" and may be applied to 1½" pipe connection with flow

h. less than 17.5 GPM

i. 1½” bodies may be utilized for 1½" Pipe and may be applied to 2" pipe connection with flows

j. less than 33 GPM

k. flows less than 55 GPM may use 2" bodies

l. flows less than 85 GPM may use 2½" bodies

m. flows less than 120 GPM may use 3" bodies

n. flows less than 165 GPM may use 4" bodies

o. flows less than 395 GPM may use 5"bodies

p. flows less than 640 GPM may use 6" bodies

q. flows less than 830 GPM may use 8" bodies

r. flows less than 1235 GPM may use 10" bodies

36.3 DUCT-COIL AND TERMINAL-UNIT-COIL; HOT AND CHILLED WATER SYSTEMS

A. Control valves utilized for controlled flows shall be proportionally modulated. Control valve shall be integrated into coil assembly package. Coil assembly package shall conform to requirements of other common valves as specified in Section 23 05 15

B. Common Piping for HVAC. Coil assembly package shall:

1. Provide integrated ball valve and wye pattern strainer. Strainer shall be #20 meshes. Strainer valve shall provide pressure and temperature measurement port with integrated positive shutoff gland seal. Strainer valve shall have plugged ¼" female NPT accessory port. Strainer valve shall provide integrated ¼" ball drain valve with cap and common hose connection. Strainer valve shall provide integrated union connection and tailpiece. Strainer valve shall be provided to match flow requirements for connected control valve.

2. Provide union connection entering and leaving piping of coil. Union connection fitting shall include three accessory ¼" female NPT tapped ports for test and other HVAC devices. Provide pressure and temperature measurement ports with integrated positive shutoff gland seal in unions entering and leaving coil. Provide manual air vent in union leaving coil. Provide ¼" threaded plugs in all unused union ports. Provide union nut, tailpiece and o-ring seal, or appropriate connectors to flexible piping.

3. Provide ball shutoff valve with integrated union. Valve shall provide pressure and temperature measurement port with integrated positive shutoff gland seal. Valve shall have plugged ¼" female NPT accessory port. Provide union nut, tailpiece and o-ring seal, or appropriate connectors to flexible piping.

4. Provide flexible piping for connection to coil. Piping shall be configured such that unions are hard mounted to coil either directly or with elbows as appropriate to allow straight flexible connection without ninety degree change in direction. Flexible pipe shall be mounted between coil union and control valve or strainer valve.

XV. SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 37 - GENERAL

37.1 FRESH AIR HANDLING UNITS FOR RESIDENTIAL APARTMENTS

A. Run Conditions - Requested:

B. The unit shall run whenever

1. Any zone is occupied.
2. OR a definable number of unoccupied zones need heating or cooling.

C. Supply Air Smoke Detection:

1. The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status.
2. AHU Optimal Start:
   a. The unit shall start prior to scheduled occupancy based on the time necessary for the zones to reach their occupied setpoints. The start time shall automatically adjust based on changes in outside air temperature and zone temperatures.

D. Supply Fan:

1. The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan shall have 3 minutes (adjustable.) minimum runtime.
2. Alarms shall be provided as follows:
   a. Supply Fan Failure: Commanded on, but the status is off.
   b. Supply Fan in Hand: Commanded off, but the status is on.
   c. Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

E. Supply Air Duct Static Pressure Control:

1. The controller shall measure duct static pressure and shall modulate the supply fan VFD speed to maintain a duct static pressure set point. The supply fan VFD speed shall not drop below 30%.
2. Alarms shall be provided as follows:
   a. High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.
   b. Low Supply Air Static Pressure: If the supply air static pressure is 25% less than setpoint.
   c. Supply Fan VFD Fault.

F. Return Fan:

1. The return fan shall run whenever the supply fan runs.
2. Alarms shall be provided as follows:
   a. Return Fan Failure: Commanded on, but the status is off.
   b. Return Fan in Hand: Commanded off, but the status is on.
   c. Return Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).
   d. Return Fan VFD Fault.

G. Return Fan Tracking:

1. The return fan VFD shall modulate in unison with the supply fan VFD. The return fan VFD shall track the supply fan VFD at 80% of the supply fan VFD speed. The return fan VFD speed shall not drop below 20%.

H. Heat Recovery Wheel - Constant Speed:

1. The controller shall run the heat recovery wheel for energy recovery as follows.

a. Cooling Recovery Mode:

1) The controller shall measure the heat wheel discharge air temperature and run the heat wheel to maintain a set point 1°C less than the unit supply air temperature set point. The heat wheel shall run for cool recovery whenever:

2) The unit's return air temperature is 3°C or more below the outside air temperature.

3) AND the unit is in a cooling mode.

4) AND the supply fan is on.

b. Heating Recovery Mode:

1) The controller shall measure the heat wheel discharge air temperature and run the heat wheel to maintain a set point 1°C greater than the unit supply air temperature set point. The heat wheel shall run for heat recovery whenever:

2) The unit's return air temperature is 3°C or more above the outside air temperature.

3) AND the unit is in a heating mode.

4) AND the economizer (if present) is off.

5) AND the supply fan is on.

I. Periodic Self-Cleaning:

1. The heat wheel self-cleaning system shall run on periodic basis as per manufacturers recommendation.

2. Alarms shall be provided as follows:

a. Heat Wheel Rotation Failure: Commanded on, but the status is off.

b. Heat Wheel in Hand: Commanded off, but the status is on.

c. Heat Wheel Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

J. Supply Air Temperature Setpoint - Fixed:

1. The controller shall monitor the supply air temperature and shall maintain a fixed supply air temperature setpoint as specified in equipment schedule.

K. Cooling Coil Valve:

1. The controller shall measure the supply air temperature and modulate the cooling coil valve to maintain its cooling setpoint.

2. The cooling shall be enabled whenever:

a. Outside air temperature is greater than 18°C.

b. AND the supply fan status is on.

3. Alarms shall be provided as follows:

a. High Supply Air Temp: If the supply air temperature is 3°C greater than set point.

L. Low Supply Air Temperature Alarm:

1. The controller shall alarm if the supply air temperature is less than 8°C.

M. Prefilter Status:

1. The controller shall monitor the prefilter status.

2. Alarms shall be provided as follows:

3. Prefilter Change Required: Prefilter differential pressure exceeds pressure drop through dirty filter (at the end of its life) as per manufacturer data.

N. Final Filter Status:

1. The controller shall monitor the final filter status.

2. Alarms shall be provided as follows:

a. Final Filter Change Required: Final filter differential pressure exceeds pressure drop through dirty filter(at the end of its life) as per manufacturer data.

O. Return Air Carbon Dioxide (CO2) Concentration Monitoring & Control:

1. The controller shall measure the return air CO2 levels. The amount of fresh air delivered to each floor shall not allow the CO2 Levels to rise 600 PPM (adjustable) above the atmospheric concentration levels which is 400 ppm (1000 ppm absolute), in all circumstances,. The CO2 sensors shall sense the real time CO2 concentration and compare it with the anchor point CO2 concentration, If the sensed CO2 concentration is found offset from anchor point, the motorized damper on each floor shall be commanded to open or close to introduce appropriate quantity of fresh air to bring the CO2 levels close to the anchor point value. The Motorized damper shall be equipped with Air flow station for better control over fresh air.

2. The VFD of the Fresh air handling unit shall be modulated based on signals from Static pressure sensor. The VFD of the Fresh air handling unit shall not ramp down below 30% of its full speed in order to maintain a minimum of 30-40% base ventilation rate at all times

3. Alarms shall be provided as follows:

a. High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000ppm (adj.) when in the unit is running.

P. Return Air Temperature:

1. The controller shall monitor the return air temperature and use as required for setpoint control.

2. Alarms shall be provided as follows:

a. High Return Air Temp: If the return air temperature is greater than 33°C (adj.).

b. Low Return Air Temp: If the return air temperature is less than 18°C (adj.).

Q. Supply Air Temperature:

1. The controller shall monitor the supply air temperature.

2. Alarms shall be provided as follows:

a. High Supply Air Temp: If the supply air temperature is greater than 24°C (adj.).

b. Low Supply Air Temp: If the supply air temperature is less than 8°C (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Supply Air Static Pressure	x								x	x	x
Outside Air Temp	x								x		x
Exhaust Air Temp	x								x		x
Heat Wheel Discharge Air Temp	x								x		x

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Return Air Carbon Dioxide PPM	x								x		x
Return Air Temp	x								x		x
Supply Air Temp	x								x		x
Supply Air Humidity	x										x
Supply Duct Air Flow - CFM	x								x		x
Return Duct Air Flow - CFM	x								x		x
Supply Fan VFD Speed		x							x		x
Return Fan VFD Speed		x							x		x
Cooling Valve		x							x		x
Supply/Return modulating Damper/floor/wing		x									x
Supply Air Smoke Detector			x						x	x	x
Supply Fan VFD Fault			x							x	x
Supply Fan Status			x						x		x
Return Fan VFD Fault			x							x	
Return Fan Status			x						x		x
Heat Wheel Status			x						x		x
Prefilter Status			x						x		
Final Filter Status			x						x		
SA/RA Damper Position Status			x								x
Supply Fan Start/Stop				x					x		x
Return Fan Start/Stop				x					x		x
Heat Wheel Start/Stop				x					x		x
Heat Wheel Bypass Dampers				x					x		x
Supply Air Damper Open/Close Command				x							x
Return Air Damper Open/Close Command				x							x
Supply Air Static Pressure Setpoint					x				x		x
Supply Air Temp Setpoint					x				x		x
Fresh Air Temp/RH					x						x
BTU Consumed					x				x		x
FAHU Electrical Energy					x				x		x
High Supply Air Static Pressure										x	
Low Supply Air Static Pressure										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
Return Fan Failure										x	
Return Fan in Hand										x	
Return Fan Runtime Exceeded										x	
Heat Wheel Rotation Failure										x	
Heat Wheel in Hand										x	

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Heat Wheel Runtime Exceeded										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Prefilter Change Required										x	x
Final Filter Change Required										x	x
High Return Air Carbon Dioxide Concentration										x	
High Return Air Humidity										x	
Low Return Air Humidity										x	
High Return Air Temp										x	
Low Return Air Temp										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Totals	10	4	9	6	5	0	0	0	26	26	33
Total Hardware (30)					Total Software (58)						

37.2 AIR HANDLING UNIT - CAFE, MAIN LOBBY

A. Run Conditions - Scheduled:

B. The unit shall run based upon an operator adjustable schedule.

C. Supply Air Smoke Detection:

1. The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status.

D. AHU Optimal Start:

The unit shall start prior to scheduled occupancy based on the time necessary for the zones to reach their occupied setpoints. The start time shall automatically adjust based on changes in outside air temperature and zone temperatures.

E. Supply Fan:

1. The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties. To prevent short cycling, the supply fan shall have a 3 minute (adj.) minimum runtime.

2. Alarms shall be provided as follows:

a. Supply Fan Failure: Commanded on, but the status is off.

b. Supply Fan in Hand: Commanded off, but the status is on.

c. Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

F. Supply Air Duct Static Pressure Control:

1. The controller shall measure duct static pressure and modulate the supply fan VFD speed to maintain a duct static pressure setpoint. The speed shall not drop below 30% (adj.). The static pressure setpoint shall be reset based on zone cooling requirements.

2. Alarms shall be provided as follows:

a. High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.

b. Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than setpoint.

c. Supply Fan VFD Fault.

G. Supply Air Temperature Setpoint - Optimized:

1. The controller shall monitor the supply air temperature and shall maintain a supply air temperature set point reset based on zone cooling requirements.

2. The supply air temperature setpoint shall be reset based on zone cooling requirements as follows:

a. The initial supply air temperature setpoint shall be 12.5°C (adj.).

b. As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 11.5°C (adj.).

c. As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 14°C (adj.).

H. Cooling Coil Valve:

1. The controller shall measure the supply air temperature and modulate the cooling coil valve to maintain its cooling setpoint.

2. The cooling shall be enabled whenever:

a. Outside air temperature is greater than 15.5°C (adj.).

b. AND the supply fan status is on.

3. Alarms shall be provided as follows:

a. High Supply Air Temp: If the supply air temperature is 3°C (adj.) greater than setpoint.

I. Low Supply Air Temperature Alarm:

1. The controller shall alarm if the supply air temperature is less than 8°C (adj.).

2. The outside and exhaust air dampers shall close and the return air damper shall open when the unit is off. If Optimal Start Up is available the mixed air damper shall operate as described in the occupied mode except that the outside air damper shall modulate to fully close.

J. Minimum Outside Air Ventilation - Carbon Dioxide (CO2) Control:

1. When in the occupied mode, the controller shall measure the return air CO2 levels and modulate the outside air dampers open on rising CO2 concentrations, overriding normal damper operation to maintain a CO2 setpoint of 600 ppm (adj.).above CO2 concentration level in the atmosphere which is 400 ppm. (thus 1000 ppm absolute CO2 levels).

K. Prefilter Status:

1. The controller shall monitor the prefilter status.

2. Alarms shall be provided as follows:

a. Prefilter Change Required: Prefilter differential pressure exceeds pressure drop through dirty filter (at the end of its life) as per manufacturer data

L. Final Filter Status:

1. The controller shall monitor the final filter status.

2. Alarms shall be provided as follows:

a. Final Filter Change Required: Final filter differential pressure exceeds pressure drop through dirty filter (at the end of its life) as per manufacturer data.

M. Return Air Carbon Dioxide (CO2) Concentration Monitoring:

1. The controller shall measure the return air CO2 levels.

2. Alarms shall be provided as follows:

a. High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000ppm (adjustible.) when in the unit is running.

N. Return Air Temperature:

1. The controller shall monitor the return air temperature and use as required for setpoint control.

2. Alarms shall be provided as follows:

a. High Return Air Temp: If the return air temperature is greater than 33°C (adj.).

b. Low Return Air Temp: If the return air temperature is less than 8°C (adj.).

O. Supply Air Temperature:

1. The controller shall monitor the supply air temperature.

2. Alarms shall be provided as follows:

a. High Supply Air Temp: If the supply air temperature is greater than 49°C (adj.).

b. Low Supply Air Temp: If the supply air temperature is less than 8°C (adj.).

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Supply Air Static Pressure	x								x	x	x
Mixed Air Temp	x								x		x
Return Air Carbon Dioxide PPM	x								x		x
Return Air Temp	x								x		x
Supply Air Temp	x								x		x
Supply Fan VFD Speed		x							x		x
Cooling Valve		x							x		x
Mixed Air Dampers		x							x		x
Supply Air Smoke Detector			x						x	x	x
Supply Fan VFD Fault			x							x	x
Supply Fan Status			x						x		x
Prefilter Status			x						x		
Final Filter Status			x						x		
Supply Damper Open/Close Sts			x								x
Supply Fan Start/Stop				x					x		x
Supply Damper Open/Close CMD				x							x
Supply Air Static Pressure Setpoint					x				x		x
Supply Air Temp Setpoint					x				x		x
Economizer Mixed Air Temp Setpoint					x				x		x
RA Carbon Dioxide PPM Setpoint					x				x		x
Fresh Air Temp & Humidity					x						x
BTU Consumption					x				x		x
AHU Electrical Energy Consumption					x				x		x
Schedule								x			
High Supply Air Static Pressure										x	
Low Supply Air Static Pressure										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
High Supply Air Temp										x	
Low Supply Air Temp										x	
Prefilter Change Required										x	x
Final Filter Change Required										x	x
High Mixed Air Temp										x	
Low Mixed Air Temp										x	
High Return Air Carbon Dioxide Concentration										x	
High Return Air Temp										x	
Low Return Air Temp										x	

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
High Supply Air Temp										x	
Low Supply Air Temp										x	
Totals	5	3	6	2	7	0	0	1	19	19	23
Total Hardware (16)					Total Software (46)						

37.3 VENTILATION FAN - FIRE & LIFE SAFETY FANS

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Fan Run Status			x							x	x
Fire Alarm Status			x							x	x
Totals	0	0	2	0	0	0	0	0	0	2	2
Total Hardware (2)					Total Software (2)						

37.4 CHILLED WATER SECONDARY/ PRIMARY PUMPS.

A. The sequence of operation of Chilled Water pumps shall be by the Chiller plant manager. Please refer section-Section 23 64 26-Rotary-Screw Water Chillers - Air cooled, for further details.

B. The Chiller plant manager shall be interfaced with BMS.

37.5 BTU METER

A. BTU Meter:

1. The controller shall monitor the BTU meter for energy consumption on a continual basis. These values shall be made available to the system at all times.

2. Alarm shall be generated as follows:

    a. Meter Failure: Sensor reading indicates a loss of pulse output from the BTU meter.

B. Peak Demand History:

1. The controller shall monitor and record the peak (high and low) demand readings from the BTU meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

C. Usage History:

1. The controller shall monitor and record BTU meter readings so as to provide an energy consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

	Hardware Points				Software Points						
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Meter Input	x										
Demand					x				x		x
Peak Today									x		x
Peak Month-to-Date									x		x
Peak Year-to-Date									x		x
Usage Today									x		x
Usage Month-to-Date									x		x
Usage Year-to-Date									x		x
Meter Failure										x	

	Hardware Points				Software Points					
Point Name	AI	AO	BI	BO	AV	BV	Loop	Sched	Trend	Alarm	Show On Graphic
Totals	1	0	0	0	1	0	0	0	7	1	7
Total Hardware (1)					Total Software (9)						

PART 38 - PLUMBING SEQUENCES

38.1 BOOSTER PUMPS

A. The following is the sequence of operation for a variable speed, 2-pump domestic water pump package equipped with individual variable frequency drives. The unit must be powered and the individual pumps in the auto position for the sequence to occur.

1. The pump designated as the lead pump shall run maintaining a constant system pressure.
2. The pump controller compares a signal from the discharge pressure transducer to the desired set point value. The lead pump speed will ramp up in order to satisfy the set point pressure.
3. Once the lead pump exceeds its best-operating-point (BOP) the first lag pump is started following a 10 second time delay.
4. Once the lag pump is called on a minimum run timer (MRT) shall begin counting to ensure that the pump runs fora minimum of 5 minutes. The MRT shall be adjustable through the operator interface.
5. When the 2 pumps are running and are operating at a point below the BOP and the lag pump minimum run timer having timed out, the lag pump will ramp down in speed and turn off. The lead pump will continue to operate and meet system requirements based on the set point pressure. Steps 2-5 are repeated in order to satisfy the building requirements.
6. The lead pump shall alternate after every 24 hours via a real time clock. A time clock will bring on the second pump, for a period of 5 seconds both pumps will operate at which point the first pump on will be shut off.
7. An Aqua stat connected to the pump seal chambers monitors the water temperature and energizes a solenoid that will allow water to drain and prevent the pumps from overheating during long periods of low demand.
8. Systems equipped with a "No-Flow" shutdown will stop when the pump controller determines there has been a "No-Flow" condition for a continuous 2-minute period. The lead pump will start again once a drop in pressure of at least 5 psi is measured on the discharge of the system.
9. The system can be manually operated by means of the virtual HOA selector buttons provided on the touch screen

38.2 WATER METERS

A. All Water Meters shall be interfaced with BMS to allow for central Monitoring and Data Logging for all major uses. For Location of Water meters please refer water supply drawings.

38.3 IRRIGATION WATER TRANSFER PUMPS

A. Input Device: Domestic water tank level switch

B. Output Device: Water transfer pump starter

C. Action: The transfer pump(s) start/stop command shall be interlocked with the Hi/lo levels of the tanks (hardwired).

D. Comment: Start/Stop of the water transfer/booster pumps shall be through hardwire interlock from the level switches, no controls shall be taken over BMS, only monitoring points as indicated under section 230993A shall be taken over BMS for report and alarm purposes.

E. Display:

1. Irrigation water tanks level transmission.
2. Irrigation water tank Hi-Lo level indication
3. Storage water tank Hi-Hi & Lo-Lo level alarm
4. Transfer pump(s) run indication.
5. Transfer pump(s) trip status
6. Transfer pump(s) mismatch alarm
7. Transfer pump (s) multistate alarm

PART 39 - DRAINAGE SEQUENCES

39.1 SUMP PUMP

A. Input Device: Sump pit level switch

B. Output Device: Pump starter

C. Action: The sump pump(s) start/stop command shall be interlocked with the Hi/lo levels of the tanks.

D. Alarm: in case of hi level of sump pit, and failure of pumps, an alarm shall be annunciated with high priority.

E. Display:

1. Sump pit Hi-Lo level indication
2. Sump pit Hi-Lo level alarm
3. Pump(s) run indication
4. Pump(s) trip status
5. Pump(s) auto/manual status
6. Pump(s) mismatch alarm
7. Pump(s) multistate alarm

XVI. HYDRONIC PIPING

GENERAL

40.1 RELATED DOCUMENTS

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

40.2 SUMMARY

A. This Section includes pipe and fitting materials, joining methods, special-duty valves, and specialties for the following:

1. Hot-water heating piping.
2. Chilled-water piping.
3. Condenser-water piping.
4. Makeup-water piping.
5. Condensate-drain piping.
6. Blowdown-drain piping.
7. Air-vent piping.
8. Safety-valve-inlet and -outlet piping.

B. Related Sections include the following:

1. Division 23 Section "Hydronic Pumps" for pumps, motors, and accessories for hydronic piping.

40.3 DEFINITIONS

A. PTFE: Polytetrafluoroethylene.

40.4 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of not less the 16 Bar.

B. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

40.5 SUBMITTALS

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

1. Plastic pipe and fittings with solvent cement.
2. Pressure-seal fittings.
3. Valves. Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
4. Air control devices.
5. Chemical treatment.
6. Hydronic specialties.

B. ESTIDAMA Submittal:

1. Product Data for Lbi-2.1: For solvent cements and adhesive primers, including printed statement of VOC content.

C. Shop Drawings: Detail, at 1:50 scale, the piping layout, fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to the building structure. Detail location of anchors, alignment guides, and expansion joints and loops.

D. Welding certificates.

E. Qualification Data: For Installer.

F. Field quality-control test reports.

G. Operation and Maintenance Data: For air control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

H. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

40.6 QUALITY ASSURANCE

A. Installer Qualifications:

1. Installers of Pressure-Sealed Joints: Installers shall be certified by the 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 processes and operators according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

C. Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with provisions in ASME B31 Series, "Code for Pressure Piping."
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

D. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 01.

40.7 EXTRA MATERIALS

A. Differential Pressure Meter: For each type of balancing valve and automatic flow control valve, include flow meter, probes, hoses, flow charts, and carrying case.

PART 41 - PRODUCTS

41.1 STEEL PIPE AND FITTINGS

SERVICE	TYPE
Chilled Water Piping 2" Dia. and under.	Black Steel ERW Schedule 40, ASTM A 53
Chilled Water Piping 2 1/2" Dia. and over.	Black Steel ERW Schedule 40, ASTM A 53
All Drain Piping: (Condensate riser, concealed areas)	uPVC Class E with solvent welded joints
Condensate piping for AHU units in Plant Rooms	Insulated GI SCHEDULE 40

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; type, grade, and wall thickness as indicated in Part 3 "Piping Applications" Article.

B. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in Part 3 "Piping Applications" Article, to suit system working pressure.

C. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in Part 3 "Piping Applications" Article, to suit system working pressure.

D. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 25, 125, and 250; , to suit system working pressure; raised ground face, and bolt holes spot faced as indicated in Part 3 "Piping Applications" Article.

E. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

F. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

G. Grooved Mechanical-Joint Fittings and Couplings:

1. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron; ASTM A 47/A 47M, Grade 32510 malleable iron; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.
2. Couplings: Ductile- or malleable-iron housing and synthetic rubber gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

H. Steel Pressure-Seal Fittings:

1. Housing: Steel.
2. O-Rings and Pipe Stop: EPDM.
3. Tools: Manufacturer's special tool.
4. Minimum 2070-kPa working-pressure rating at 110 deg C.

I. Steel Pipe Nipples: ASTM A 733 made of same materials and wall thicknesses as pipe in which they are installed.

41.2 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, 3.2-mm maximum thickness unless thickness or specific material is indicated.
    a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
    b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.

D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

E. Brazing Filler Metals: AWS A5.8, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.

F. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

G. Solvent Cements for Joining Plastic Piping:

1. CPVC Piping: ASTM F 493.
    a. Use CPVC solvent cement that has a VOC content of 490 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
    b. Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.
    a. Use PVC solvent cement that has a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
    b. Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

H. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

41.3 TRANSITION FITTINGS

A. Plastic-to-Metal Transition Fittings:

1. CPVC and PVC one-piece fitting with one threaded brass or copper insert and one Schedule 80 solvent-cement-joint end.

B. Plastic-to-Metal Transition Unions:

1. MSS SP-107, CPVC and PVC union. Include brass or copper end, Schedule 80 solvent-cement-joint end, rubber gasket, and threaded union.

41.4 DIELECTRIC FITTINGS

A. Description: Combination fitting of copper-alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials.

B. Insulating Material: Suitable for system fluid, pressure, and temperature.

C. Dielectric Unions:

1. Factory-fabricated union assembly, for 1725-kPa minimum working pressure at 82 deg C.

D. Dielectric Flanges:

1. Factory-fabricated companion-flange assembly, for 2070-kPa minimum working pressure as required to suit system pressures.

E. Dielectric-Flange Kits:

1. Companion-flange assembly for field assembly. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.

2. Separate companion flanges and steel bolts and nuts shall have 2070-kPa minimum working pressure where required to suit system pressures.

F. Dielectric Couplings:

1. Galvanized-steel coupling with inert and noncorrosive thermoplastic lining; threaded ends; and 2070-kPa minimum working pressure at 107 deg C.

41.5 VALVES

A. Gate, Globe, Check, Ball, and Butterfly Valves: Comply with requirements specified in Division 23 Section "General-Duty Valves for HVAC Piping."

B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Division 23 Section "Instrumentation and Control for HVAC."

C. Bronze, Calibrated-Orifice, Balancing Valves:

1. Body: Bronze, ball or plug type with calibrated orifice or venturi.
2. Ball: Brass or stainless steel.
3. Plug: Resin.
4. Seat: PTFE.
5. End Connections: Threaded or socket.
6. Pressure Gage Connections: Integral seals for portable differential pressure meter.
7. Handle Style: Lever, with memory stop to retain set position.
8. CWP Rating: based on system working pressure.

D. Maximum Operating Temperature: 121 deg C.

E. Cast-Iron or Steel, Calibrated-Orifice, Balancing Valves:

1. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
2. Ball: Brass or stainless steel.
3. Stem Seals: EPDM O-rings.
4. Disc: Glass and carbon-filled PTFE.
5. Seat: PTFE.
6. End Connections: Flanged or grooved.
7. Pressure Gage Connections: Integral seals for portable differential pressure meter.
8. Handle Style: Lever, with memory stop to retain set position.
9. CWP Rating: As per system working pressure.
10. Maximum Operating Temperature: 121 deg C.

F. Diaphragm-Operated, Pressure-Reducing Valves:

1. Body: Bronze or brass.
2. Disc: Glass and carbon-filled PTFE.
3. Seat: Brass.
4. Stem Seals: EPDM O-rings.
5. Diaphragm: EPT.

6. Low inlet-pressure check valve.
7. Inlet Strainer: stainless steel, removable without system shutdown.
8. Valve Seat and Stem: Noncorrosive.
9. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

G. Automatic Flow-Control Valves:
1. Body: Brass or ferrous metal.
2. Piston and Spring Assembly: Stainless steel tamper proof, self cleaning, and removable.
3. Combination Assemblies: Include bonze or brass-alloy ball valve.
4. Identification Tag: Marked with zone identification, valve number, and flow rate.
5. Size: Same as pipe in which installed.
6. Performance: Maintain constant flow, plus or minus 5 percent over system pressure fluctuations.
7. Minimum CWP Rating: based on system working pressure.
8. Maximum Operating Temperature: 121 deg.

H. Manual Air Vents:
1. Body: Bronze.
2. Internal Parts: Nonferrous.
3. Operator: Screwdriver or thumbscrew.
4. Inlet Connection DN 15.
5. Discharge Connection: DN 6
6. CWP Rating: subject to working pressure.
7. Maximum Operating Temperature: 107 deg C.

I. Automatic Air Vents:
1. Body: Bronze or cast iron.
2. Internal Parts: Nonferrous.
3. Operator: Noncorrosive metal float.
4. Inlet Connection: DN 15.
5. Discharge Connection: DN 8.
6. CWP Rating: based on system working pressure.).
7. Maximum Operating Temperature: 116 deg C..

J. Expansion Tanks:
1. Tank: Welded steel, rated for suitable working pressure and 191 deg C maximum operating temperature, with taps in bottom of tank for tank fitting and taps in end of tank for gage glass. Tanks shall be factory tested with taps fabricated and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
2. Air-Control Tank Fitting: Cast-iron body, copper-plated tube, brass vent tube plug, and stainless-steel ball check, 379-L unit only; sized for compression-tank diameter. Provide tank fittings suitable for 860-kPa working pressure and 121 deg C maximum operating temperature.

3. Tank Drain Fitting: Brass body, nonferrous internal parts; 860-kPa working pressure and 240 deg F (116 deg C) maximum operating temperature; constructed to admit air to compression tank, drain water, and close off system.

4. Gauge Glass: Full height with dual manual shutoff valves, 20-mm diameter guage glass, and slotted-metal glass guard.

K. Diaphragm/Bladder-Type Expansion Tanks:

1. Tank: Welded steel, rated suitable working pressure and 375 deg F (191 deg C) maximum operating temperature. Factory test with taps fabricated and supports installed and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

2. Diaphragm/Bladder: Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.

3. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

L. In-Line Air Separators:

1. Tank: One-piece cast iron with an integral weir constructed to decelerate system flow to maximize air separation.

2. Maximum Working Pressure: Matching with system pressure.

3. Maximum Operating Temperature: Up to 149 deg C.

M. Air Purges:

1. Body: Cast iron with internal baffles that slow the water velocity to separate the air from solution and divert it to the vent for quick removal.

2. Maximum Working Pressure: 1035 kPa.

3. Maximum Operating Temperature: 121 deg C.

41.6 HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers:

1. Body: ASTM A 126, Class C cast iron with bolted cover and bottom drain connection.

2. End Connections: Threaded ends for DN 50 and smaller; flanged ends for DN 65 and larger.

3. Strainer Screen: 40mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.

4. CWP Rating: Based on system working pressure.

B. Spherical, Rubber, Flexible Connectors:

1. Body: Fiber-reinforced rubber body.

2. End Connections: Steel flanges drilled to align with Classes 150 and 300 steel flanges.

3. Performance: Capable of misalignment.

4. CWP Rating: 1035 kPa.

5. Maximum Operating Temperature: 121 deg C.

C. Expansion fittings are specified in Division 23 Section "Expansion Fittings and Loops for HVAC Piping."

PART 42 - EXECUTION

42.1 PIPING APPLICATIONS

A. Hot-water heating piping, shall be of the following:

1. Schedule 80 CPVC plastic pipe and fittings and solvent-welded joints.

B. Chilled-water piping, DN 50 and smaller shall be of the following:

1. ASTM A 53 Schedule 40 black steel pipe; Class 300, malleable-iron fittings; and threaded joints.

C. Chilled-water piping, DN 65 and larger, shall be of the following:

1. ASTM A 53Schedule 40 black steel pipe; Class 300, malleable-iron fittings; and flanged joints.

D. Condenser-water piping, DN 50 and smaller shall be of the following:

1. ASTM A 53Schedule 80 black steel pipe; Class 300, malleable-iron fittings; and threaded joints.

E. Condenser-water piping, DN 65 and larger shall be of the following:

1. ASTM A 53Schedule 80 black steel pipe; Class 300, malleable-iron fittings; and flanged joints.

F. Makeup-water piping shall be of the following:

1. Schedule 80 PVC plastic pipe and fittings, and solvent-welded joints.

G. Condensate-Drain Piping: Schedule 40 PVC plastic pipe and fittings and solvent-welded joints.

H. Condensate-Drain Piping: Schedule 40 PVC plastic pipe and fittings and solvent-welded joints.

42.2 VALVE APPLICATIONS

A. Install shut off-duty valves at each branch connection to supply mains, and at supply connection to each piece of equipment.

B. Install calibrated-orifice, balancing valves at each branch connection to return main.

C. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.

D. Install check valves at each pump discharge and elsewhere as required to control flow direction.

E. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; and pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.

F. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

42.3 PIPING INSTALLATIONS

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicate piping locations and arrangements if such were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on 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, DN 20 ball valve, and short DN 20 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using 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 Division 23 Section "General-Duty Valves for HVAC Piping."

Q. Install unions in piping, DN 50 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, DN 65 and larger, at final connections of equipment and elsewhere as indicated.

S. Install strainers on inlet side of each control valve, pressure-reducing valve, solenoid valve, in-line pump, and elsewhere as indicated. Install DN 20 nipple and ball valve in blow down connection of strainers DN 50 and larger. Match size of strainer blow off connection for strainers smaller than DN 50.

T. Install expansion loops, expansion joints, anchors, and pipe alignment guides as specified in Division 23 Section "Expansion Fittings and Loops for HVAC Piping."

U. Identify piping as specified in Division 23 Section "Identification for HVAC Piping and Equipment."

V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Division 23 Section "Sleeves and Sleeve Seals for HVAC Piping."

W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Division 23 Section "Sleeves and Sleeve Seals for HVAC Piping."

42.4 HANGERS AND SUPPORTS

A. Hanger, support, and anchor devices are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment." Comply with the following requirements for maximum spacing of supports.

B. Seismic restraints are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

C. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping less than 6 m long.

2. Adjustable roller hangers and spring hangers for individual horizontal piping 6 m or longer.

3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 6 m or longer, supported on a trapeze.

4. Spring hangers to support vertical runs.

5. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

6. On plastic pipe, install pads or cushions on bearing surfaces to prevent hanger from scratching pipe.

D. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:

1. DN 20: Maximum span, 2.1 m; minimum rod size, 6.4 mm.
2. DN 25: Maximum span, 2.1 m; minimum rod size, 6.4 mm.
3. DN 40: Maximum span, 2.7 m; minimum rod size, 10 mm.
4. DN 50: Maximum span, 3 m; minimum rod size, 10 mm.
5. DN 65: Maximum span, 3.4 m; minimum rod size, 10 mm.
6. DN 80: Maximum span, 3.7 m; minimum rod size, 10 mm.
7. DN 100: Maximum span, 4.3 m; minimum rod size, 13 mm.
8. DN 150: Maximum span, 5.2 m; minimum rod size, 13 mm.
9. DN 200: Maximum span, 5.8 m; minimum rod size, 16 mm.
10. DN 250: Maximum span, 6.1 m; minimum rod size, 19 mm.
11. DN 300: Maximum span, 7 m; minimum rod size, 22 mm.
12. DN 350: Maximum span, 7.6 m; minimum rod size, 25 mm.
13. DN 400: Maximum span, 8.2 m; minimum rod size, 25 mm.
14. DN 450: Maximum span, 8.5 m; minimum rod size, 32 mm.
15. DN 500: Maximum span, 9.1 m; minimum rod size, 32 mm.

E. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:

1. DN 20: Maximum span, 1.5 m; minimum rod size, 6.4 mm.
2. DN 25: Maximum span1.8 m; minimum rod size, 6.4 mm.
3. DN 40: Maximum span, 2.4 m; minimum rod size, 10 mm.
4. DN 50: Maximum span, 2.4 m; minimum rod size, 10 mm.
5. DN 65: Maximum span, 2.7 m; minimum rod size, 10 mm.
6. DN 80: Maximum span, 3 m; minimum rod size, 10 mm.

F. Plastic Piping Hanger Spacing: Space hangers according to pipe manufacturer have written instructions for service conditions. Avoid point loading. Space and install hangers with the fewest practical rigid anchor points.

G. Support vertical runs at roof, at each floor, and at 3-m intervals between floors.

42.5 PIPE JOINT CONSTRUCTION

A. Join pipe and fittings according to the following requirements and Division 23 Sections specifying piping systems.

B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

D. 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.

E. 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.

F. 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.

G. Welded Joints: Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.

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

I. Plastic Piping Solvent-Cemented Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:

1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
3. PVC Pressure Piping: Join ASTM D 1785 schedule number, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule number PVC pipe and socket fittings according to ASTM D 2855.
4. PVC Nonpressure Piping: Join according to ASTM D 2855.

J. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid, grooved-end-pipe couplings.

K. Pressure-Sealed Joints: Use manufacturer-recommended tool and procedure. Leave insertion marks on pipe after assembly.

42.6 HYDRONIC SPECIALTIES INSTALLATION

A. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.

B. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Manual vents at heat-transfer coils and elsewhere as required for air venting.

C. Install in-line air separators in pump suction. Install drain valve on air separators DN 50 and larger.

D. Install bypass chemical feeders in each hydronic system where indicated, in upright position with top of funnel not more than 1200 mm above the floor. Install feeder in minimum DN 20 bypass line, from main with full-size, full-port, ball valve in the main between bypass connections. Install DN 20 pipe from chemical feeder drain, to nearest equipment drain and include a full-size, full-port, ball valve.

E. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure tank is properly charged with air to suit system Project requirements.

42.7 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install ports for pressure gages and thermometers at coil inlet and outlet connections according to Division 23 Section "Meters and Gages for HVAC Piping."

42.8 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:

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 "SE" values 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.

XVII. HYDRONIC PUMPS

PART 43 - GENERAL

43.1 RELATED DOCUMENTS

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

43.2 SUMMARY

A. This Section includes the following:

1. Close-coupled, in-line centrifugal pumps.
2. Close-coupled, end-suction centrifugal pumps.
3. Automatic condensate pump units.

43.3 DEFINITIONS

A. Buna-N: Nitrile rubber.

B. EPT: Ethylene propylene terpolymer.

43.4 SUBMITTALS

A. Product Data: Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated. Indicate pump's operating point on curves.

B. Shop Drawings: Show pump layout and connections. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.

C. Wiring Diagrams: Power, signal, and control wiring.

D. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.

E. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

43.5 QUALITY ASSURANCE

A. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

B. Product Options: Drawings indicate size, profiles, and dimensional requirements of hydronic pumps and are based on the specific system indicated.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

D. UL Compliance: Comply with UL 778 for motor-operated water pumps.

E. Factory test all chilled water pumps, before shipping, to verify the performance.

1. The tests shall be witnessed by the Engineer at the place where pumps are being tested. Notify Engineer 30 days in advance of testing. Contractor to bear all costs for testing, traveling, boarding/lodging for witnessing the tests.
2. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

43.6 DELIVERY, STORAGE, AND HANDLING

A. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.

B. Store pumps in dry location.

C. Retain protective covers for flanges and protective coatings during storage.

D. Protect bearings and couplings against damage from sand, grit, and other foreign matter.

E. Comply with pump manufacturer's written rigging instructions.

43.7 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases.

43.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Mechanical Seals: One mechanical seal(s) for each pump.

PART 44 - PRODUCTS

44.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

44.2 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically. Rate pump for: refer to equipment schedules.

B. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, and threaded companion-flange connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Steel, with copper-alloy shaft sleeve or Stainless steel.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N or EPT bellows and gasket. Include water slinger on shaft between motor and seal.
5. Packing Seal: Stuffing box, with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
6. Pump Bearings: Permanently lubricated ball bearings

C. Motor: Single speed, with permanently lubricated (grease-lubricated for motors over 5HP) ball bearings, unless otherwise indicated; and rigidly mounted to pump casing. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

D. Capacities and Characteristics:

1. Refer to equipment schedules.

44.3 CLOSE-COUPLED, END-SUCTION CENTRIFUGAL PUMPS

A. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally. Rate pump for; refer to equipment schedules.

B. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, drain plug at bottom and air vent at top of volute, threaded gage tappings at inlet and outlet, and flanged connections.
2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Trim impeller to match specified performance.
3. Pump Shaft: Steel, with copper-alloy shaft sleeve or Stainless Steel.
4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N or EPT bellows and gasket. Include water slinger on shaft between motor and seal.
5. Pump Bearings: Permanently lubricated ball bearings.

6. Motor: Single speed, with permanently lubricated ball bearings, unless otherwise indicated; rigidly mounted to pump casing with integral pump support. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

44.4 AUTOMATIC CONDENSATE PUMP UNITS

A. Description: Packaged units with corrosion-resistant pump, plastic tank with cover, and automatic controls. Include factory- or field-installed check valve and a 72-inch-(1800-mm-) minimum, electrical power cord with plug.

44.5 PUMP SPECIALTY FITTINGS

A. Suction Diffuser: Angle pattern, 175-psig (1204-kPa) pressure rating, cast-iron body and end cap, pump-inlet fitting; with bronze startup and bronze or stainless-steel permanent strainers; bronze or stainless-steel straightening vanes; drain plug; and factory-fabricated support.

B. Triple-Duty Valve: Angle or straight pattern, 175-psig (1204-kPa) pressure rating, cast-iron body, pump-discharge fitting; with drain plug and bronze-fitted shutoff, balancing, and check valve features. Brass gage ports with integral check valve, and orifice for flow measurement.

PART 45 - EXECUTION

45.1 EXAMINATION

A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of work.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.

C. Examine foundations and inertia bases for suitable conditions where pumps are to be installed.

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

45.2 CONCRETE BASES

A. Install concrete bases of dimensions indicated for pumps and controllers.

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

45.3 PUMP INSTALLATION

A. Comply with HI 1.4.

B. Install pumps with access for periodic maintenance including removal of motors, impellers, couplings, and accessories.

C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.

D. Install continuous-thread hanger rods and elastomeric hangers, spring hangers or spring hangers with vertical-limit stop of sufficient size to support pump weight. Vibration isolation devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Fabricate brackets or supports as required. Hanger and support materials are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

E. Suspend vertically mounted, in-line centrifugal pumps independent of piping. Install pumps with motor and pump shafts vertical. Use continuous-thread hanger rods and elastomeric hangers, spring hangers or spring hangers with vertical-limit stop of sufficient size to support pump weight. Vibration isolation devices are specified in Division 21 Section "Vibration and Seismic Controls for Fire-Suppression Piping and Equipment." Hanger and support materials are specified in Division 22 Section "Hangers and Supports for Plumbing Piping and Equipment/Hangers and Supports for HVAC Piping and Equipment."

F. Set base-mounted pumps on concrete foundation. Disconnect coupling before setting. Do not reconnect couplings until alignment procedure is complete.

G. Support pump baseplate on rectangular metal blocks and shims, or on metal wedges with small taper, at points near foundation bolts to provide a gap of 3/4 to 1-1/2 inches (19 to 38 mm) between pump base and foundation for grouting.

H. Adjust metal supports or wedges until pump and driver shafts are level. Check coupling faces and suction and discharge flanges of pump to verify that they are level and plumb.

I. Automatic Condensate Pump Units: Install units for collecting condensate and extend to open drain.

45.4 ALIGNMENT

A. Align pump and motor shafts and piping connections after setting on foundation, grout has been set and foundation bolts have been tightened, and piping connections have been made.

B. Comply with pump and coupling manufacturers' written instructions.

C. Adjust pump and motor shafts for angular and offset alignment by methods specified in HI 1.1-1.5, "Centrifugal Pumps for Nomenclature, Definitions, Application and Operation and HI 2.1-2.5, " Vertical Pumps for Nomenclature, Definitions, Application and Operation."

D. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

45.5 CONNECTIONS

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

B. Install piping adjacent to machine to allow service and maintenance.

C. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.

E. Install check valve and throttling valve or triple-duty valve on discharge side of pumps.

F. Install Y-type strainer and shutoff valve on suction side of pumps.

G. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

H. Install pressure gages on pump suction and discharge, at integral pressure-gage tapping, or install single gage with multiple input selector valve.

I. Install check valve and gate or ball valve on each condensate pump unit discharge.

J. Install electrical connections for power, controls, and devices.

K. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

L. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

45.6 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.
2. Check piping connections for tightness.
3. Clean strainers on suction piping.
4. Perform the following startup checks for each pump before starting:
    a. Verify bearing lubrication.
    b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
    c. Verify that pump is rotating in the correct direction.
5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.

6. Start motor.
7. Open discharge valve slowly.

45.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

XVIII. HVAC CHEMICAL TREATMENT

PART 46 - GENERAL

46.1 RELATED DOCUMENTS

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

46.2 SUMMARY

A. This Section includes the following HVAC water-treatment systems:

1. Bypass chemical-feed equipment and controls.
2. Biocide chemical-feed equipment and controls.
3. Chemical treatment test equipment.
4. HVAC water-treatment chemicals.

46.3 DEFINITIONS

A. EEPROM: Electrically erasable, programmable read-only memory.

B. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

C. TDS: Total dissolved solids.

46.4 PERFORMANCE REQUIREMENTS

A. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or the environment.

B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

C. Closed hydronic systems, including hot-water heating and chilled water, shall have the following water qualities:

1. pH: Maintain a value within 9.0 to 10.5.
2. "P" Alkalinity: Maintain a value within 100 to 500 ppm.
3. Boron: Maintain a value within 100 to 200 ppm.
4. Retain first subparagraph below for systems that do not contain glycol.
5. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
6. Soluble Copper: Maintain a maximum value of 0.20 ppm.
7. TDS: Maintain a maximum value of 10 ppm.
8. Ammonia: Maintain a maximum value of 20 ppm.
9. Free Caustic Alkalinity: Maintain a maximum value of 20 ppm.
10. Microbiological Limits:
    a. Total Aerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
    b. Total Anaerobic Plate Count: Maintain a maximum value of 100 organisms/ml.
    c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.

d. Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.

e. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.

D. Open hydronic systems, including condenser water, shall have the following water qualities:

1. pH: Maintain a value within 8.0 to 9.1.
2. "P" Alkalinity: Maintain a maximum value of 100 ppm.
3. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
4. Soluble Copper: Maintain a maximum value of 0.20 ppm.
5. TDS: Maintain a maximum value of 10 ppm.
6. Ammonia: Maintain a maximum value of 20 ppm.
7. Free "OH" Alkalinity: Maintain a maximum value of 0 ppm
8. Microbiological Limits:
   a. Total Aerobic Plate Count: Maintain a maximum value of 10,000 organisms/ml.
   b. Total Anaerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
   c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
   d. Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.
   e. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.
9. Polymer Testable: Maintain a minimum value within 10 to 40.

E. Passivation for Galvanized Steel: For the first 60 days of operation.

1. pH: Maintain a value within 7 to 8.
2. Calcium Carbonate Hardness: Maintain a value within 100 to 300 ppm.
3. Calcium Carbonate Alkalinity: Maintain a value within 100 to 300 ppm.

46.5 SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for the following products:

1. Bypass feeders.
2. Water meters.
3. Inhibitor injection timers.
4. pH controllers.
5. TDS controllers.
6. Biocide feeder timers.
7. Chemical solution tanks.
8. Injection pumps.
9. Ozone generators.
10. UV-irradiation units.
11. Chemical test equipment.
12. Chemical material safety data sheets.
13. Water softeners.

B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems. Include plans, elevations, sections, details, and attachments to other work.

1. Wiring Diagrams: Power and control wiring.

C. Field quality-control test reports.

D. Manufacturer Seismic Qualification Certification: Submit certification that water softeners, water filtration units and components will withstand seismic forces defined in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2. 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.

E. Operation and Maintenance Data: For sensors, injection pumps, water softeners, water filtration units and controllers to include in emergency, operation, and maintenance manuals.

F. Other Informational Submittals:

1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in the "Performance Requirements" Article above.

2. Water Analysis: Illustrate water quality available at Project site.

3. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to Architect.

G. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

46.6 QUALITY ASSURANCE

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

46.7 MAINTENANCE SERVICE

A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion, scale formation, and biological growth for cooling, chilled-water piping, heating, hot-water piping, condenser-water piping and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion, and shall include the following:

1. Initial water analysis and HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
3. Periodic field service and consultation.
4. Customer report charts and log sheets.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

PART 47 - PRODUCTS

47.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

47.2 MANUAL CHEMICAL-FEED EQUIPMENT

A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch (89-mm) fill opening in the top, and NPS 3/4 (DN 20) bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.

1. Capacity: 2 gal. (7.6 L) / 5 gal. (19 L).
2. Minimum Working Pressure: TBC.

47.3 AUTOMATIC CHEMICAL-FEED EQUIPMENT – Details TBC

A. Water Meter:

1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 150 psig (1035 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Threaded.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac; and that will close at adjustable increments of total flow.

B. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze.
3. Minimum Working-Pressure Rating: 100 psig (690 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Threaded.
7. Control: Low-voltage signal capable of transmitting 1000 feet (305 m).

C. Water Meter:

1. AWWA C701, turbine-type, totalization meter.
2. Body: Bronze or Epoxy-coated cast iron.
3. Minimum Working-Pressure Rating: 150 psig (1035 kPa).
4. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
5. Registration: Gallons (Liters) or cubic feet (cubic meters).
6. End Connections: Flanged.
7. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac; and that will close at adjustable increments of total flow.

D. Inhibitor Injection Timers:

1. Microprocessor-based controller with LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation and Control for HVAC."
2. Programmable timers with infinite adjustment over full range, and mounted in cabinet with hand-off-auto switches and status lights.
3. Test switch.
4. Hand-off-auto switch for chemical pump.
5. Illuminated legend to indicate feed when pump is activated.
6. Programmable lockout timer with indicator light. Lockout timer to deactivate the pump and activate alarm circuits.
7. LCD makeup totalizer to measure amount of makeup and bleed-off water from two water meter inputs.

E. pH Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 14 units. Incorporate solid-state integrated circuits and digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation and Control for HVAC."
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal pH indication.
5. High or low pH alarm light, trip points field adjustable; with silence switch.
6. Hand-off-auto switch for acid pump.
7. Internal adjustable hysteresis or deadband.

F. TDS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation and Control for HVAC."
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal conductance indication.
5. High or low conductance alarm light, trip points field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.
9. Bleed Valves:
   a. Cooling Systems: Forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.

G. Biocide Feeder Timer:

1. Microprocessor-based controller with digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation and Control for HVAC."
2. 24-hour timer with 14-day skip feature to permit activation any hour of day.
3. Precision, solid-state, bleed-off lockout timer and clock-controlled biocide pump timer. Prebleed and bleed lockout timers.
4. Solid-state alternator to enable use of two different formulations.
5. 24-hour display of time of day.
6. 14-day display of day of week.
7. Battery backup so clock is not disturbed by power outages.
8. Hand-off-auto switches for biocide pumps.
9. Biocide A and Biocide B pump running indication.

H. Chemical Solution Tanks:
1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: TBC.

I. Chemical Solution Injection Pumps:
1. Self-priming, positive-displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

J. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A 269, Type 304, stainless steel for steam boiler injection assemblies.

K. Injection Assembly:
1. Quill: Minimum NPS 1/2 (DN 15) with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: Three / Two-piece, stainless steel as described in "Stainless-Steel Pipes and Fittings" Article below; and selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 600 psig (4137 kPa) at 200 deg F (93 deg C).

47.4 STAINLESS-STEEL PIPES AND FITTINGS
1. Stainless-Steel Tubing: Comply with ASTM A 269, Type 316.
2. Stainless-Steel Fittings: Complying with ASTM A 815/A 815M, Type 316, Grade WP-S.
3. Two-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, carbon-

filled TFE seats, threaded body design with adjustable stem packing, threaded ends, and 250-psig (1725-kPa) SWP and 600-psig (4140-kPa) CWP ratings.

4. Three-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, threaded body design with adjustable stem packing, threaded ends, and 150-psig (1035-kPa) SWP and 600-psig (4140-kPa) CWP rating.

47.5 CHEMICAL TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TDS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers, and oxidizing biocide test for open cooling systems.

B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

1. Two-station rack for closed-loop systems.
2. Four -station rack for open systems.

47.6 CHEMICALS

A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment, and that can attain water quality specified in Part 1 "Performance Requirements" Article.

B. Water Softener Chemicals:

1. Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range with good resistance to bead fracture from attrition or shock. Resin exchange capacity minimum 30,000 grains/cu. ft. (69 kg/cu. m) of calcium carbonate of resin when regenerated with 15 lb (6.8 kg) of salt.
2. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are not acceptable.

PART 48 - EXECUTION

48.1 WATER ANALYSIS

A. Perform an analysis of supply water to determine quality of water available at Project site.

48.2 INSTALLATION

A. Install chemical application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.

B. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. Refer to Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for seismic restraints.

C. Install water testing equipment on wall near water chemical application equipment.

D. Install interconnecting control wiring for chemical treatment controls and sensors.

E. Mount sensors and injectors in piping circuits.

F. Bypass Feeders: Install in closed hydronic systems, including hot-water heating, chilled water, and equipped with the following:

1. Install bypass feeder in a bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
2. Install water meter in makeup water supply.
3. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
4. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.
5. Install a swing check on inlet after the isolation valve.

G. Install automatic chemical-feed equipment for steam boiler and steam condensate systems and include the following:

1. Install makeup water softener.
2. Install water meter in makeup water supply.
3. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
    a. Pumps shall operate for timed interval when contacts close at water meter in makeup water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
4. Install test equipment and furnish test-kit to Owner.
5. Install TDS controller with sensor and bleed valves.
    a. Bleed valves shall cycle to maintain maximum TDS concentration.
6. Install inhibitor injection timer with injection pumps and solution tanks.
    a. Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection. Injection pump shall discharge into main steam supply header.

H. Install automatic chemical-feed equipment for condenser water and include the following:

1. Install makeup water softener.
2. Install water meter in makeup water supply.
3. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
    a. Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
4. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
5. Install TDS controller with sensor and bleed valves.
    a. Bleed valves shall cycle to maintain maximum TDS concentration.
6. Install pH sensor and controller with injection pumps and solution tanks.
    a. Injector pumps shall operate to maintain required pH.
7. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.
    a. Injection pumps shall operate to feed biocide on an alternating basis.

48.3 WATER SOFTENER INSTALLATION

A. Install water softener equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.

B. Install seismic restraints for tanks and floor-mounting accessories and anchor to building structure. Refer to Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for seismic restraints.

C. Install brine lines and fittings furnished by equipment manufacturer but not factory installed.

D. Prepare mineral-tank distribution system and underbed for minerals and place specified mineral into mineral tanks.

E. Install water-testing sets on wall adjacent to water softeners.

48.4 CONNECTIONS

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

B. Install piping adjacent to equipment to allow service and maintenance.

C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Division 23 Section "Common Work Results for HVAC."

D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Division 23 Section "General-Duty Valves for HVAC Piping."

E. Refer to Division 22 Section "Domestic Water Piping Specialties" for backflow preventers required in makeup water connections to potable-water systems.

F. Confirm applicable electrical requirements in Division 26 Sections for connecting electrical equipment.

G. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

H. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

48.5 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

B. Perform tests and inspections and prepare test reports.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

C. Tests and Inspections:

1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.
4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
7. Cap and subject piping to static water pressure of 50 psig (345 kPa) above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
8. Repair leaks and defects with new materials and retest piping until no leaks exist.

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

E. Sample boiler water at one-week intervals after boiler startup for a period of five weeks, and prepare test report advising Owner of changes necessary to adhere to Part 1 "Performance Requirements" Article for each required characteristic. Sample boiler water at four week intervals following the testing noted above to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section.

F. At four-week intervals following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis advising Owner of changes necessary to adhere to Part 1 "Performance Requirements" Article.

G. Comply with ASTM D 3370 and with the following standards:

1. Silica: ASTM D 859.
2. Steam System: ASTM D 1066.
3. Acidity and Alkalinity: ASTM D 1067.
4. Iron: ASTM D 1068.
5. Water Hardness: ASTM D 1126.

48.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

B. Training: Provide a "how-to-use" self-contained breathing apparatus video that details exact operating procedures of equipment.

XIX. METAL DUCTS

GENERAL

48.7 RELATED DOCUMENTS

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

48.8 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings. **(For outdoor ducts and ducts run through shafts)**
2. Fire rated Ducts **(Emergency ducts and Kitchen extract)**
3. Single-wall round ducts and fittings.
4. Sheet metal materials.
5. Duct liner.
6. Sealants and gaskets.
7. Hangers and supports.
8. Seismic-restraint devices.

B. Related Sections:

1. Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Division 23 Section "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.
3. Division 23 Section "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

48.9 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article.

B. Structural Performance: Duct hangers and supports and seismic restraints shall withstand the effects of gravity and seismic loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7 SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."

1. Seismic Hazard Level A: Seismic force to weight ratio, 0.48.
2. Seismic Hazard Level B: Seismic force to weight ratio, 0.30.
3. Seismic Hazard Level C: Seismic force to weight ratio, 0.15.
4. Hazard level has to be confirmed with Local Authority; protection to be provided to meet the appropriate hazard level.

48.10 SUBMITTALS

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

1. Liners and adhesives.
2. Sealants and gaskets.
3. Seismic-restraint devices.

B. Shop Drawings:

1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
2. Factory- and shop-fabricated ducts and fittings.
3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
4. Elevation of top of ducts.
5. Dimensions of main duct runs from building grid lines.
6. Fittings.
7. Reinforcement and spacing.
8. Seam and joint construction.
9. Penetrations through fire-rated and other partitions.
10. Equipment installation based on equipment being used on Project.
11. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
12. Hangers and supports, including methods for duct and building attachment, seismic restraints, and vibration isolation.

C. Delegated-Design Submittal:

1. Sheet metal thicknesses.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Materials, fabrication, assembly, and spacing of hangers and supports.
5. Design Calculations: Calculations, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation for selecting hangers and supports and seismic restraints.

D. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

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

E. Welding certificates.

F. Field quality-control reports.

G. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

48.11 QUALITY ASSURANCE

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

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
3. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.
4. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

PART 49 - PRODUCTS

49.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-4, "Transverse (Girth) Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-5, "Longitudinal Seams - Rectangular Ducts," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 2, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

49.2 FIRE RATED DUCTS (EMERGENCY DUCTS AND KITCHEN EXTRACT)

A. Fire Rated Duct shall be use for applications such as Car Park Ventilation, Smoke Extraction, Kitchen Extraction and Pressurization Systems.

B. The Fire Rated ductwork shall be rated for both Type A (Fire Outside) and Type B (Fire Inside and Outside) fires in accordance with BS 476; Part 24:1987 (ISO 6944: 1985), designed in accordance to BS 5588: Part 9:1989, Method 3.

C. The Duct work system shall meet the requirements for stability, integrity and insulation to the service provided eg. Smoke Extract, Kitchen Extract as per BS 476 part 24.

D. Under normal non-fire operating conditions, the ductwork should conform to the Class C pressure/leakage classification of the current HVCA DW/144 specification for sheet.

E. All Hanging and support accessories required for installation of the Duct work shall be in line with BS 476: Part 24.

F. Sealants, Gaskets and Flanges shall be provided by the Fire Rated Duct Manufacturer. The complete Fire Rated Duct system shall be rated for 2 Hours as per Local Civil Defense Requirements.

G. Upon completion of installation a certificate of conformity shall be issued by the Supplier /Manufacturer to confirm that the system has been manufactured and installed correctly.

H. • Fire Rated Duct product shall be approved by Local Civil Defense.

49.3 SINGLE-WALL ROUND DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

B. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

C. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).

D. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Transverse Joints - Round Duct," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

E. Transverse Joints in Ducts Larger Than 60 Inches (1524 mm) in Diameter: Flanged.

F. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Seams - Round Duct and Fittings," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

G. Fabricate round ducts larger than 90 inches (2286 mm) in diameter with butt-welded longitudinal seams.

H. Fabricate flat-oval ducts larger than 72 inches (1830 mm) in width (major dimension) with butt-welded longitudinal seams.

I. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "90 Degree Tees and Laterals," and Figure 3-5, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

49.4 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90 (Z275).
2. Finishes for Surfaces Exposed to View: Mill phosphatized.

C. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G60 (Z180) or G90 (Z275).
2. Minimum Thickness for Factory-Applied PVC Coating: 4 mils (0.10 mm) thick on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil (0.025 mm) thick on opposite surface.
3. Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.

D. Carbon-Steel Sheets: Comply with ASTM A 1008/A 1008M, with oiled, matte finish for exposed ducts.

E. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.

F. Aluminum Sheets: Comply with ASTM B 209 (ASTM B 209M) Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

G. Factory- or Shop-Applied Antimicrobial Coating:

1. Apply to the surface of sheet metal that will form the interior surface of the duct. An untreated clear coating shall be applied to the exterior surface.
2. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Coating containing the antimicrobial compound shall have a hardness of 2H, minimum, when tested according to ASTM D 3363.
4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
5. Shop-Applied Coating Color: Black or White.
6. Antimicrobial coating on sheet metal is not required for duct containing liner treated with antimicrobial coating.

H. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

I. Tie Rods: Galvanized steel, 1/4-inch (6-mm) minimum diameter for lengths 36 inches (900 mm) or less; 3/8-inch (10-mm) minimum diameter for lengths longer than 36 inches (900 mm).

49.5 DUCT LINER

A. Fibrous-Glass Duct Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.
2. Antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Solvent or Water-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.

B. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.
2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

C. Natural-Fiber Duct Liner: 85 percent cotton, 10 percent borate, and 5 percent polybinding fibers, treated with a microbial growth inhibitor and complying with NFPA 90A or NFPA 90B.

1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.
2. Maximum Thermal Conductivity: 0.24 Btu x in./h x sq. ft. x deg F (0.034 W/m x K) at 75 deg F (24 deg C) mean temperature when tested according to ASTM C 518.
3. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to ASTM E 84; certified by an NRTL.

4. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

D. Insulation Pins and Washers:

1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- (2.6-mm-) or 0.135-inch- (3.5-mm-) diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.

2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick galvanized steel, aluminum or stainless steel; with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

E. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-19, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.

2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.

3. Butt transverse joints without gaps, and coat joint with adhesive.

4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.

5. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.

6. Secure liner with mechanical fasteners 4 inches (100 mm) from corners and at intervals not exceeding 12 inches (300 mm) transversely; at 3 inches (75 mm) from transverse joints and at intervals not exceeding 18 inches (450 mm) longitudinally.

7. Secure transversely oriented liner edges facing the airstream with metal nosing’s that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:

   a. Fan discharges.

   b. Intervals of lined duct preceding unlined duct.

   c. Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm (12.7 m/s) or where indicated.

   d. Retain first subparagraph below if ducts with air velocities higher than 4000 fpm (20.3 m/s) are anticipated; indicate locations of double-wall ducts on Drawings. Use solid-metal (unperforated) inner ducts for material-handling exhaust systems.

   e. Sheet Metal Inner Duct Perforations: 3/32-inch (2.4-mm) diameter, with an overall open area of 23 percent.

8. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

49.6 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

C. Solvent-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Base: Synthetic rubber resin.
3. Solvent: Toluene and heptane.
4. Solids Content: Minimum 60 percent.
5. Shore A Hardness: Minimum 60.
6. Water resistant.
7. Mold and mildew resistant.
8. VOC: Maximum 395 g/L.
9. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
10. Service: Indoor or outdoor.
11. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.

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

F. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg (0.14 L/s per sq. m at 250 Pa) and shall be rated for 10-inch wg (2500-Pa) static-pressure class, positive or negative.
2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.

3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

49.7 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1 (Table 4-1M), "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct."

D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.

E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.

F. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

H. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

49.8 SEISMIC-RESTRAINT DEVICES

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. See the Evaluations in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" for discussion on seismic-restraint capacities and rating services.

C. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.

D. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.

E. Restraint Cables: ASTM A 603, galvanized or ASTM A 492, stainless-steel cables with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for restraining cable service; and with an automatic-locking and clamping device or double-cable clips.

F. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

PART 50 - EXECUTION

50.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install round ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch (25 mm), plus allowance for insulation thickness.

I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches (38 mm).

K. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Division 23 Section "Air Duct Accessories" for fire and smoke dampers.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "Duct Cleanliness for New Construction Guidelines."

50.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

50.3 ADDITIONAL INSTALLATION REQUIREMENTS FOR COMMERCIAL KITCHEN HOOD EXHAUST DUCT

A. Install commercial kitchen hood exhaust ducts without dips and traps that may hold grease, and sloped a minimum of 2 percent to drain grease back to the hood.

B. Install fire-rated access panel assemblies at each change in direction and at maximum intervals of 12 feet (3.7 m) in horizontal ducts, and at every floor for vertical ducts, or as indicated on Drawings. Locate access panel on top or sides of duct a minimum of 1-1/2 inches (38 mm) from bottom of duct.

C. Do not penetrate fire-rated assemblies except as allowed by applicable building codes and authorities having jurisdiction.

50.4 DUCT SEALING

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

50.5 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches (100 mm) thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches (100 mm) thick.
5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1 (Table 4-1M), "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches (610 mm) of each elbow and within 48 inches (1200 mm) of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum interval of 16 feet (5 m).

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

50.6 SEISMIC-RESTRAINT-DEVICE INSTALLATION

A. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems."

1. Space lateral supports a maximum of 40 feet (12 m) o.c., and longitudinal supports a maximum of 80 feet (24 m o.c.
2. Brace a change of direction longer than 12 feet (3.7 m).

B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.

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

D. Install cable restraints on ducts that are suspended with vibration isolators.

E. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction.

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

G. Drilling for and Setting Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.

2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.

3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.

4. Set anchors to manufacturer's recommended torque, using a torque wrench.

5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

50.7 CONNECTIONS

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

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

50.8 PAINTING

A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer.

50.9 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:

1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.

2. Test the following systems:

a. Ducts with a Pressure Class Higher Than 3-Inch wg (750 Pa): Test representative duct sections, selected by Engineer from sections installed, totaling no less than 25 percent of total installed duct area for each designated pressure class.

3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.

4. Test for leaks before applying external insulation.

5. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.

6. Give seven days' advance notice for testing.

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."
   a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

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

E. Prepare test and inspection reports.

50.10 DUCT CLEANING

A. Clean new duct system(s) before testing, adjusting, and balancing.

B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Division 23 Section "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

D. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.

3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.

4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.

5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.

6. Provide drainage and cleanup for wash-down procedures.

7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

50.11 START UP

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

50.12 DUCT SCHEDULE

A. Fabricate ducts with galvanized sheet steel except as otherwise indicated.

B. Supply Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

a. Pressure Class: Positive 1-inch wg (250 Pa)

b. Minimum SMACNA Seal Class: B

c. SMACNA Leakage Class for Rectangular: 12

d. SMACNA Leakage Class for Round and Flat Oval: 12

2. Ducts Connected to Constant-Volume Air-Handling Units:

a. Pressure Class: Positive 2-inch wg (500 Pa)

b. Minimum SMACNA Seal Class: B.

c. SMACNA Leakage Class for Rectangular: 12.

d. SMACNA Leakage Class for Round and Flat Oval: 12.

3. Ducts Connected to Variable-Air-Volume Air-Handling Units:

a. Pressure Class: Positive 3-inch wg (750 Pa)

b. Minimum SMACNA Seal Class: B.

c. SMACNA Leakage Class for Rectangular: 12

d. SMACNA Leakage Class for Round and Flat Oval: 12

C. Return Ducts:

1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:

a. Pressure Class: Positive or negative 1-inch wg (250 Pa)

b. Minimum SMACNA Seal Class: B.

c. SMACNA Leakage Class for Rectangular: 12

d. SMACNA Leakage Class for Round and Flat Oval: 12

2. Ducts Connected to Air-Handling Units:

a. Pressure Class: Positive or negative 2-inch wg (500 Pa)

b. Minimum SMACNA Seal Class: B.

c. SMACNA Leakage Class for Rectangular: 12.

d. SMACNA Leakage Class for Round and Flat Oval: 12.

D. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:

a. Pressure Class: Negative 1-inch wg (250 Pa)

b. Minimum SMACNA Seal Class: B if negative pressure, and A if positive pressure.

c. SMACNA Leakage Class for Rectangular: 12.

d. SMACNA Leakage Class for Round and Flat Oval: 12.

2. Ducts Connected to Air-Handling Units

a. Pressure Class: Positive or negative 2-inch wg (500 Pa).

b. Minimum SMACNA Seal Class: B if negative pressure, and A if positive pressure.

c. SMACNA Leakage Class for Rectangular: 12.

d. SMACNA Leakage Class for Round and Flat Oval: 12.

3. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.

a. Exposed to View: Type 304, stainless-steel sheet, No. 4 or No. 3 finish.

b. Concealed: Type 304, stainless-steel sheet, No. 2D finish or Carbon-steel sheet.

c. Welded seams and joints.

d. Pressure Class: Positive or negative 2-inch wg (500 Pa) or 3-inch wg (750 Pa)

e. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.

f. SMACNA Leakage Class: 3.

4. Ducts Connected to Dishwasher Hoods:

a. Type 304, stainless-steel sheet.

b. Exposed to View: No. 4 or No. 3 finish.

c. Concealed: No. 2D finish.

d. Welded seams and flanged joints with water tight EPDM gaskets.

e. Pressure Class: Positive or negative 2-inch wg (500 Pa)

f. Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.

g. SMACNA Leakage Class: 3.

5. Ducts Connected to Fans Exhausting Laboratory and Process (ASHRAE 62.1, Class 3 and 4) Air: Not Applicable.

E. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: Galvanized steel or carbon steel coated with zinc-chromate primer.

2. PVC-Coated Ducts:

a. Exposed to Airstream: Match duct material.

b. Not Exposed to Airstream: Match duct material.

3. Stainless-Steel Ducts:

a. Exposed to Airstream: Match duct material.

b. Not Exposed to Airstream: Match duct material.

4. Aluminum Ducts: Aluminum or galvanized sheet steel coated with zinc chromate.

F. Liner:

1. Supply Air Ducts: Flexible elastomeric, 1 inch (25 mm thick.

2. Return Air Ducts: Flexible elastomeric, 1 inch (25 mm thick.
3. Exhaust Air Ducts: Flexible elastomeric 1 inch (25 mm thick.
4. Supply Fan Plenums: Flexible elastomeric1 inch (25 mm) thick.
5. Return- and Exhaust-Fan Plenums: Flexible elastomeric 2 inches (51 mm) thick.
6. Transfer Ducts: Flexible elastomeric 1 inch (25 mm) thick.

G. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Elbows."
    a. Velocity 1000 fpm (5 m/s) or Lower:
        1) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.
        2) Mitered Type RE 4 without vanes.
    b. Velocity 1000 to 1500 fpm (5 to 7.6 m/s):
        1) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.
        2) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.
        3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-3, "Vanes and Vane Runners," and Figure 2-4, "Vane Support in Elbows."
    c. Velocity 1500 fpm (7.6 m/s) or Higher:
        1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
        2) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
        3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-3, "Vanes and Vane Runners," and Figure 2-4, "Vane Support in Elbows."
2. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Elbows."
    a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
    b. Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
    c. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-3, "Vanes and Vane Runners," and Figure 2-4, "Vane Support in Elbows."
3. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-3, "Round Duct Elbows."
    a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.
        1) Velocity 1000 fpm (5 m/s) or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
        2) Velocity 1000 to 1500 fpm (5 to 7.6 m/s): 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
        3) Velocity 1500 fpm (7.6 m/s) or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
    b. Round Elbows, 12 Inches (305 mm) and Smaller in Diameter: Stamped or pleated.
    c. Round Elbows, 14 Inches (356 mm) and Larger in Diameter: Standing seam or welded.

H. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-6, "Branch Connections."
    a. Rectangular Main to Rectangular Branch: 45-degree entry.
    b. Rectangular Main to Round Branch: Spin in.
2. Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "90 Degree Tees and Laterals," and Figure 3-5, "Conical Tees." Saddle taps are permitted in existing duct.
    a. Velocity 1000 fpm (5 m/s) or Lower: 90-degree tap.
    b. Velocity 1000 to 1500 fpm (5 to 7.6 m/s): Conical tap.
    c. Velocity 1500 fpm (7.6 m/s) or Higher: 45-degree lateral.

XX. HVAC CASINGS

PART 51 - GENERAL

51.1 RELATED DOCUMENTS

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

51.2 SUMMARY

A. Section Includes:

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

51.3 PERFORMANCE REQUIREMENTS

A. Static-Pressure Classes:

1. Upstream from Fan(s): 2-inch wg (500 Pa).

2. Downstream from Fan(s): 3-inch wg (750 Pa).

B. Acoustical Performance:

1. NRC: 1.09 according to ASTM C 423.

2. STC: 40 according to ASTM E 90.

C. Structural Performance:

1. Casings shall be fabricated to withstand 133 percent of the indicated static pressure without structural failure. Wall and roof deflection at the indicated static pressure shall not exceed 1/8 inch per foot (0.97 mm per meter) of width.

a. Fabricate outdoor casings to withstand wind load of 15 lbf/sq. ft. (720 N/sq. m) and snow load of 30 lbf/sq. ft. (1440 N/sq. m).

D. Seismic Performance: HVAC casings shall withstand the effects of earthquake motions determined according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

51.4 SUBMITTALS

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

1. Factory-fabricated casings.

2. Liners and adhesives.

3. Sealants and gaskets.

4. Seismic-restraint devices.

B. LEED Submittals: Not Required.

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

1. Detail HVAC casing assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

2. Sheet metal thickness.

3. Reinforcement and spacing.

4. Seam and joint construction.

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

D. Welding certificates.

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

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

F. Field quality-control reports.

G. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

51.5 QUALITY ASSURANCE

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

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

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

51.6 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in structural documentation.

B. Coordinate sizes and locations of steel supports with structural engineer.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations with structural engineer.

PART 52 - PRODUCTS

52.1 GENERAL CASING FABRICATION REQUIREMENTS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 6, "Equipment and Casings," for acceptable materials, material thicknesses, and casing construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

1. Fabricate casings with more than 3-inch wg (750-Pa) negative static pressure according to SMACNA's "Rectangular Industrial Duct Construction Standards."
2. Casings with more than 2-inch wg (500-Pa) positive static pressure may be fabricated according to SMACNA's "Rectangular Industrial Duct Construction Standards."
3. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
4. Exterior Surface Galvanized Coating Designation: G90 (Z275).
5. Interior Surface Galvanized Coating Designation:
   a. Sections Not Exposed to Moisture: G60 (Z180) or G90 (Z275).
   b. Sections Housing and Downstream from Cooling Coil and Humidifiers: G90 (Z275).

B. Stainless Steel: ASTM A 480/A 480M, Type 304 or Type 316, and having a No. 2D finish.

C. Factory- or Shop-Applied Antimicrobial Coating:

1. Apply to the interior sheet metal surfaces of casing in contact with the airstream. Apply untreated clear coating to the exterior surface.
2. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Coating containing the antimicrobial compound shall have a hardness of 2H minimum when tested according to ASTM D 3363.
4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 according to UL 723; certified by an NRTL.
5. Applied Coating Color: Standard

D. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

E. Sealing Requirement: SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Seal Class A. Seal all seams, joints, connections, and abutments to building.

F. Penetrations: Seal all penetrations airtight. Cover with escutcheons and gaskets, or fill with suitable compound so there is no exposed insulation. Provide shaft seals where fan shafts penetrate casing.

G. Access Doors: Fabricate access doors according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 6-11, "Casing Access Doors - 2-inch wg (500 Pa)," and Figure 6.12, "Casing Access Doors - 3-10-inch wg (750-2500 Pa)"; and according to pressure class of the plenum or casing section in which access doors are to be installed.

1. Size: 20 by 54 inches (500 by 1370 mm).
2. Vision Panel: Double-glazed, wire-reinforced safety glass with an airspace between panes and sealed with interior and exterior rubber seals.
3. Hinges: Piano or butt hinges and latches, number and size according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
4. Latches: Minimum of two wedge-lever-type latches, operable from inside and outside.

5. Neoprene gaskets around entire perimeters of door frames.

6. Doors shall open against air pressure.

H. Condensate Drain Pans: Formed sections of G90 (Z275) coated, galvanized sheet steel complying with requirements in ASHRAE 62.1. Pans shall extend a minimum of 12 inches (300 mm) past coil.

1. Double-wall construction shall have space between walls filled with foam insulation and sealed moisture tight.

2. Intermediate drain pan or drain trough shall collect condensate from top coil for units with stacked coils or stacked eliminators.

3. Insulation: Polystyrene or polyurethane.

4. Slopes shall be in a minimum of two planes to collect condensate from cooling coils (including coil piping connections and return bends), eliminators, and humidifiers when units are operating at maximum catalogued face velocity across cooling coil.

5. Each drain pan connection shall have a trap. Drain traps with depth and height differential between inlet and outlet equal or greater to the design static pressure plus 2-inch wg (500 Pa). Include slab height in trap calculation.

52.2 SHOP-FABRICATED CASINGS

A. Single- and Double-Wall Casings: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.

B. Double-Wall Casing Inner Panel: Solid sheet steel. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.

C. Interstitial Insulation: Polyurethane foam complying with NFPA 90A or NFPA 90B.

D. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

E. Interstitial Insulation: Flexible-elastomeric duct liner complying with ASTM C 534, Type II for sheet materials and with NFPA 90A or NFPA 90B.

F. Fabricate casings with standing seams and angle-iron reinforcements unless otherwise indicated.

G. Fabricate close-off sheets from casing to dampers, filter frames, and coils and between stacked coils. Use galvanized sheet steel of same thickness as casing and with a galvanized coating designation of G90 (Z275).

H. Bolt close-off sheets to frame flanges and housings. Support coils on stands fabricated from galvanized-steel angles or channels.

I. Reinforce casings with galvanized-steel angles.

52.3 MANUFACTURED CASINGS

A. Description: Double-wall, insulated, pressurized equipment casing.

B. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

C. Double-Wall Panel Fabrication: Solid, galvanized sheet steel exterior wall and solid galvanized sheet steel interior wall; with space between walls filled with insulation.

1. Wall Thickness: 2 inches (50 mm).

2. Fabricate with a minimum number of joints.
3. Weld exterior and interior walls to perimeter; to interior, longitudinal, galvanized-steel channels; and to box-end internal closures. Paint welds.
4. Sheet metal thickness shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for static-pressure class indicated for casing.
5. Double-Wall Casing Inner Panel: Solid sheet steel.
6. Fill each panel assembly with insulating material that is noncombustible, inert, mildew resistant and vermin proof and that complies with NFPA 90A.
7. Fabricate panels with continuous tongue-and-groove or self-locking joints effective inside and outside each panel.

D. Trim Items: Fabricate from a minimum of 0.052-inch (1.3-mm) galvanized sheet steel, furnished in standard lengths for field cutting.

52.4 CASING LINER

A. Fibrous-Glass Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.
2. Antimicrobial Erosion-Resistant Coating: Apply to surface of the liner that will form the interior surface of casing to act as a moisture repellent and an erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Solvent or Water-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.

B. Flexible-Elastomeric Casing Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1, and with NFPA 90A or NFPA 90B.
1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.
2. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
3. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

C. Natural-Fiber Casing Liner: 85 percent cotton, 10 percent borate, and 5 percent polybinding fibers, treated with a microbial growth inhibitor, and complying with NFPA 90A or NFPA 90B.
1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.
2. Maximum Thermal Conductivity: 0.24 Btu x in./h x sq. ft. x deg F (0.034 W/m x K) at 75 deg F (24 deg C) mean temperature when tested according to ASTM C 518.
3. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
4. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

D. Insulation Pins and Washers:

1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- (2.6-mm-) or 0.135-inch- (3.5-mm-) diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.
2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick, galvanized or stainless steel, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

E. Shop or Factory Application of Casing Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-19, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of casing liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of casing liner is prohibited.
2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
3. Butt transverse joints without gaps, and coat joint with adhesive.
4. Fold and compress liner in corners of casings or cut and fit to ensure butted-edge overlapping.
5. Secure liner with mechanical fasteners 4 inches (100 mm) from corners and at intervals not exceeding 12 inches (300 mm) transversely; at 3 inches (75 mm) from transverse joints and at intervals not exceeding 18 inches (450 mm) longitudinally.
6. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from casing wall. Fabricate edge facings at the following locations:
   a. Fan discharges.
   b. Intervals of lined casing preceding unlined duct.
   c. Upstream edges of transverse joints in casings where air velocities are higher than 2500 fpm (12.7 m/s) or where indicated.
7. Secure insulation between perforated sheet metal inner wall of same thickness as specified for outer wall. Use mechanical fasteners that maintain inner wall at uniform distance from outer wall without compressing insulation.

52.5 SEALANT MATERIALS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
8. Service: Indoor or outdoor.

9. Substrate: Compatible with galvanized sheet steel or stainless steel.

C. Solvent-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Base: Synthetic rubber resin.
3. Solvent: Toluene and heptane.
4. Solids Content: Minimum 60 percent.
5. Shore A Hardness: Minimum 60.
6. Water resistant.
7. Mold and mildew resistant.
8. VOC: Maximum 395 g/L.
9. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
10. Service: Indoor or outdoor.
11. Substrate: Compatible with galvanized sheet steel or stainless steel.

D. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single component, acid curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.

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

PART 53 - EXECUTION

53.1 EXAMINATION

A. Examine concrete bases, roof curbs and steel supports for compliance with requirements for conditions affecting installation and performance of HVAC casings.

B. Examine casing insulation materials and liners before installation. Reject casings that are wet, moisture damaged, or mold damaged.

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

53.2 INSTALLATION

A. Install casings according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

B. Equipment Mounting: Install HVAC casings on concrete base. Comply with requirements for concrete base specified by the structural engineer.

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centres around the full perimeter of concrete base.

2. For supported casings, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

4. Install anchor bolts to elevations required for proper attachment to supported equipment.

C. Install seismic restraints on casings. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

D. Apply sealant to joints, connections, and mountings.

E. Field-cut openings for pipe and conduit penetrations; insulate and seal according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

F. Support casings on floor or foundation system. Secure and seal to base.

G. Support components rigidly with ties, braces, brackets, seismic restraints and anchors of types that will maintain housing shape and prevent buckling.

H. Align casings accurately at connections, with 1/8-inch (3-mm) misalignment tolerance and with smooth interior surfaces.

53.3 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Perform field tests and inspections according to SMACNA's "HVAC Air Duct Leakage Test Manual."

2. Test the following systems:

a. Systems required by ASHRAE/IESNA 90.1-2004.

3. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Give seven days' advance notice for testing.

4. Determine leakage from entire system or section of system by relating leakage to surface area of test section. Comply with requirements for leakage classification of ducts connected to casings.

5. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.

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

C. Prepare test and inspection reports.

53.4 CLEANING

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

XXI. AIR DUCT ACCESSORIES

PART 54 - GENERAL

54.1 RELATED DOCUMENTS

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

54.2 SUMMARY

A. Section Includes:

S. Backdraft and pressure relief dampers.

T. Barometric relief dampers.

U. Manual volume dampers.

V. Control dampers.

W. Fire dampers.

X. Ceiling dampers.

Y. Smoke dampers.

Z. Combination fire and smoke dampers.

AA. Corridor dampers.

BB. Flange connectors.

CC. Duct silencers.

DD. Turning vanes.

EE. Remote damper operators.

FF. Duct-mounted access doors.

GG. Flexible connectors.

HH. Flexible ducts.

II. Duct accessory hardware.

B. Related Sections:

JJ. Division 28 Section "Fire Detection and Alarm" for duct-mounted fire and smoke detectors.

54.3 SUBMITTALS

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

KK. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.

B. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.

LL. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:

h. Special fittings.

i. Manual volume damper installations.

j. Control damper installations.

k. Fire-damper, smoke-damper, combination fire- and smoke-damper, ceiling, and corridor damper installations, including sleeves; and duct-mounted access doors and remote damper operators.

l. Retain subparagraph below if equipment includes wiring.

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

C. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.

D. Source quality-control reports.

E. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

F. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

54.4 QUALITY ASSURANCE

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with AMCA 500-D testing for damper rating.

54.5 EXTRA MATERIALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Fusible Links: Furnish quantity equal to 10 percent of amount installed.

PART 55 - PRODUCTS

55.1 MATERIALS

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G90 (Z275).

2. Exposed-Surface Finish: Mill phosphatized.

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a No. 2 finish for concealed and exposed ducts.

D. Aluminum Sheets: Comply with ASTM B 209 (ASTM B 209M), Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.

E. Extruded Aluminum: Comply with ASTM B 221 (ASTM B 221M), Alloy 6063, Temper T6.

F. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

G. Tie Rods: Galvanized steel, 1/4-inch (6-mm) minimum diameter for lengths 36 inches (900 mm) or less; 3/8-inch (10-mm) minimum diameter for lengths longer than 36 inches (900 mm).

55.2 BACKDRAFT AND PRESSURE RELIEF DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Description: Gravity balanced.

C. Maximum Air Velocity: 3000 fpm (15 m/s).

D. Maximum System Pressure: 2-inch wg (0.5 kPa).

E. Frame: 0.052-inch- (1.3-mm-) thick, galvanized sheet steel or 0.063-inch- (1.6-mm-) thick extruded aluminum.

F. Blades: Multiple single-piece blades, center-pivoted, maximum 6-inch (150-mm) width, 0.025-inch- (0.6-mm-) thick, roll-formed aluminum or 0.050-inch- (1.2-mm-) thick aluminum sheet with sealed edges.

G. Blade Action: Parallel.

H. Blade Seals: Neoprene, mechanically locked.

I. Blade Axles:

1. Material: Nonferrous metal or Aluminum.

2. Diameter: Minimum 0.20 inch (5 mm).

J. Tie Bars and Brackets: Aluminum or Galvanized steel.

K. Return Spring: Adjustable tension.

L. Bearings: Steel ball or synthetic pivot bushings.

M. Accessories:

1. Adjustment device to permit setting for varying differential static pressure.

2. Counterweights and spring-assist kits for vertical airflow installations.

3. Electric actuators.

4. Chain pulls.

5. Screen Mounting: Front mounted in sleeve.

    a. Sleeve Thickness: 20-gage (1.0-mm) minimum.

    b. Sleeve Length: 6 inches (152 mm) minimum.

6. Screen Mounting: Rear mounted.

7. Screen Material: Galvanized steel or Aluminum.

8. Screen Type: Bird.

9. 90-degree stops.

55.3 BAROMETRIC RELIEF DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Suitable for horizontal or vertical mounting.

C. Maximum Air Velocity: 2000 fpm (10 m/s).

D. Maximum System Pressure: 2-inch wg (0.5 kPa).

E. Frame: 0.064-inch- (1.6-mm-) thick, galvanized sheet steel or 0.063-inch- (1.6-mm-) thick extruded aluminum, with welded corners and mounting flange.

F. Blades:

1. Multiple, 0.025-inch- (0.6-mm-) thick, roll-formed aluminum or 0.050-inch- (1.2-mm-) thick aluminum sheet.

2. Maximum Width: 6 inches (150 mm).

3. Action: Parallel.

4. Balance: Gravity.

5. Eccentrically pivoted.

G. Blade Seals: Neoprene.

H. Blade Axles: Galvanized steel or Nonferrous metal.

I. Tie Bars and Brackets:

1. Material: Aluminum or Galvanized steel.

2. Rattle free with 90-degree stop.

J. Return Spring: Adjustable tension.

K. Bearings: Synthetic, Stainless steel or Bronze.

L. Accessories:

1. Flange on intake.

2. Adjustment device to permit setting for varying differential static pressures.

55.4 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

2. Standard leakage rating, with linkage outside airstream.

3. Suitable for horizontal or vertical applications.

4. Frames:

a. Hat-shaped, galvanized or stainless-steel channels, 0.064-inch (1.62-mm) minimum thickness.

b. Mitered and welded corners.

c. Flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

a. Multiple or single blade.

b. Parallel- or opposed-blade design.

c. Stiffen damper blades for stability.

d. Galvanized or Stainless-steel, 0.064 inch (1.62 mm) thick.

6. Blade Axles: Galvanized steel, Stainless steel or Nonferrous metal.

7. Bearings:

a. Oil-impregnated bronze, Molded synthetic or Stainless-steel sleeve.

b. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Galvanized steel.

B. Standard, Aluminum, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

2. Standard leakage rating, with linkage outside airstream.

3. Suitable for horizontal or vertical applications.

4. Frames: Hat-shaped, 0.10-inch- (2.5-mm-) thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

a. Multiple or single blade.

b. Parallel- or opposed-blade design.

c. Stiffen damper blades for stability.

d. Roll-Formed Aluminum Blades: 0.10-inch- (2.5-mm-) thick aluminum sheet.

e. Extruded-Aluminum Blades: 0.050-inch- (1.2-mm-) thick extruded aluminum.

6. Blade Axles: Galvanized steel, Stainless steel or Nonferrous metal.

7. Bearings:

a. Oil-impregnated bronze, Molded synthetic or Stainless-steel sleeve.

b. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Tie Bars and Brackets: Aluminum.

C. Low-Leakage, Steel, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

2. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.

3. Suitable for horizontal or vertical applications.

4. Frames:

a. Hat, U or Angle shaped.

b. Galvanized or Stainless-steel channels, 0.064 inch (1.62 mm) thick.

c. Mitered and welded corners.

d. Flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

a. Multiple or single blade.

b. Parallel- or opposed-blade design.

c. Stiffen damper blades for stability.

d. Galvanized or Stainless, roll-formed steel, 0.064 inch (1.62 mm) thick.

6. Blade Axles: Galvanized steel, Stainless steel or Nonferrous metal.

7. Bearings:

a. Oil-impregnated bronze, Molded synthetic or Stainless-steel sleeve.

b. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Blade Seals: Neoprene.

9. Jamb Seals: Cambered Stainless steel or Aluminum.

10. Tie Bars and Brackets: Galvanized steel or Aluminum.

11. Accessories:

a. Include locking device to hold single-blade dampers in a fixed position without vibration.

D. Low-Leakage, Aluminum, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

2. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.

3. Suitable for horizontal or vertical applications.

4. Frames: Hat, U or Angle-shaped, 0.10-inch- (2.5-mm-) thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.

5. Blades:

a. Multiple or single blade.

b. Parallel- or opposed-blade design.

c. Roll-Formed Aluminum Blades: 0.10-inch- (2.5-mm-) thick aluminum sheet.

d. OR Extruded-Aluminum Blades: 0.050-inch- (1.2-mm-) thick extruded aluminum.

6. Blade Axles: Galvanized steel, Stainless steel or Nonferrous metal.

7. Bearings:

a. Oil-impregnated bronze, Molded synthetic or Stainless-steel sleeve.

b. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

8. Blade Seals: Neoprene.

9. Jamb Seals: Cambered Stainless steel or Aluminum.

10. Tie Bars and Brackets: Galvanized steel or Aluminum.

11. Accessories:

a. Include locking device to hold single-blade dampers in a fixed position without vibration.

E. Jackshaft:

1. Size: 1-inch (25-mm) diameter.

2. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.

3. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

F. Damper Hardware:

1. Zinc-plated, die-cast core with dial and handle made of 3/32-inch- (2.4-mm-) thick zinc-plated steel, and a 3/4-inch (19-mm) hexagon locking nut.

2. Include center hole to suit damper operating-rod size.

3. Include elevated platform for insulated duct mounting.

55.5 CONTROL DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.

C. Frames:

1. Hat, U or Angle shaped.

2. Galvanized or Stainless-steel channels, 0.064 inch (1.62 mm) thick.

3. Mitered and welded corners.

D. Blades:

1. Multiple blade with maximum blade width of 8 inches (200 mm).

2. Opposed-blade design.

3. Galvanized or Stainless steel.

4. 0.064 inch (1.62 mm) thick.

5. Blade Edging: Closed-cell neoprene edging.

6. Blade Edging: Inflatable seal blade edging, or replaceable rubber seals.

E. Blade Axles: 1/2-inch- (13-mm-) diameter; galvanized steel, stainless steel or nonferrous metal; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.

1. Operating Temperature Range: From minus 40 to plus 200 deg F (minus 40 to plus 93 deg C).

F. Bearings:

1. Oil-impregnated bronze, Molded synthetic or Stainless-steel sleeve.

2. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

3. Thrust bearings at each end of every blade.

55.6 FIRE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Type: Static and dynamic; rated and labeled according to UL 555 by an NRTL.

C. Closing rating in ducts up to 4-inch wg (1-kPa) static pressure class and minimum 4000-fpm (20-m/s) velocity.

D. Fire Rating: To match wall ratings as per fire safety drawings. Typically 2 hours.

E. Frame: Curtain type with blades outside airstream; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.

1. Minimum Thickness: 0.052 or 0.138 inch (1.3 or 3.5 mm) thick, as indicated, and of length to suit application.

2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

G. Mounting Orientation: Vertical or horizontal as indicated.

H. Blades: Roll-formed, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.

I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

J. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) rated, fusible links.

55.7 CEILING DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. General Requirements:

1. Labeled according to UL 555C by an NRTL.

2. Comply with construction details for tested floor- and roof-ceiling assemblies as indicated in UL's "Fire Resistance Directory."

C. Frame: Galvanized sheet steel, round or rectangular, style to suit ceiling construction.

D. Blades: Galvanized sheet steel with refractory insulation.

E. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) rated, fusible links.

F. Fire Rating: 2 hours

55.8 SMOKE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. General Requirements: Label according to UL 555S by an NRTL.

C. Smoke Detector: Integral, factory wired for single-point connection.

D. Frame: Curtain type with blades outside airstream or Multiple-blade type; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

E. Blades: Roll-formed, horizontal, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.

F. Leakage: Class II.

G. Rated pressure and velocity to exceed design airflow conditions.

H. Mounting Sleeve: Factory-installed, 0.052-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking.

I. Damper Motors: Modulating action.

J. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section "Instrumentation and Control for HVAC." and Division 26 Sections.
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F (minus 40 deg C).
6. Nonspring-Return Motors: For dampers larger than 25 sq. ft. (2.3 sq. m), size motor for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 300 in. x lbf (34 N x m).
7. Electrical Connection: 240 V, single phase, 50 Hz.

K. Accessories:

1. Auxiliary switches for signaling, fan control and position indication.
2. Test and reset switches, damper and remote mounted.

55.9 COMBINATION FIRE AND SMOKE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Type: Static and dynamic; rated and labeled according to UL 555 and UL 555S by an NRTL.

C. Closing rating in ducts up to 4-inch wg (1-kPa) static pressure class and minimum 4000-fpm (20-m/s) velocity

D. Fire Rating: To match wall ratings as per fire safety drawings. Typically 2 hours

E. Frame: Curtain type with blades outside airstream or Multiple-blade type; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

F. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) rated, fusible links.

G. Heat-Responsive Device: Electric resettable link and switch package, factory installed, rated.

H. Smoke Detector: Integral, factory wired for single-point connection.

I. Frame: Curtain type with blades outside airstream or Multiple-blade type; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

J. Blades: Roll-formed, horizontal, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.

K. Leakage: Class II.

L. Rated pressure and velocity to exceed design airflow conditions.

M. Mounting Sleeve: Factory-installed, 0.052-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking.

N. Master control panel for use in dynamic smoke-management systems.

O. Damper Motors: Modulating action.

P. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section "Instrumentation and Control for HVAC." and Division 26 Sections.
3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).
5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F (minus 40 deg C).
6. Nonspring-Return Motors: For dampers larger than 25 sq. ft. (2.3 sq. m), size motor for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 300 in. x lbf (34 N x m).
7. Electrical Connection: 240 V, single phase, 50 Hz.

Q. Accessories:

1. Auxiliary switches for signaling, fan control and position indication.
2. Test and reset switches, damper and remote mounted.

55.10 CORRIDOR DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. General Requirements: Label combination fire and smoke dampers according to UL 555 for 1-1/2-hour rating by an NRTL.

C. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) rated, fusible links.

D. Frame: Curtain type with blades outside airstream; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

E. Blades: Roll-formed, horizontal, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.

F. Mounting Sleeve: Factory-installed, 0.052-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application.

55.11 FLANGE CONNECTORS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Description: Add-on or roll-formed, factory-fabricated, slide-on transverse flange connectors, gaskets, and components.

C. Material: Galvanized steel.

D. Gage and Shape: Match connecting ductwork.

55.12 DUCT SILENCERS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. General Requirements:

1. Factory fabricated.
2. Fire-Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials shall have flame-spread index not exceeding 25 and smoke-developed index not exceeding 50 when tested according to ASTM E 84.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

C. Shape:

1. Rectangular straight with splitters or baffles.
2. Round straight with center bodies or pods.
3. Rectangular elbow with splitters or baffles.
4. Round elbow with center bodies or pods.
5. Rectangular transitional with splitters or baffles.

D. Rectangular Silencer Outer Casing: ASTM A 653/A 653M, G90 (Z275) galvanized sheet steel, 0.040 inch (1.02 mm) thick.

E. Round Silencer Outer Casing: ASTM A 653/A 653M, G90 (Z275), galvanized sheet steel.

1. Sheet Metal Thickness for Units up to 24 Inches (600 mm) in Diameter: 0.034 inch (0.85 mm) thick.
2. Sheet Metal Thickness for Units 26 through 40 Inches (660 through 1000 mm) in Diameter: 0.040 inch (1.02 mm) thick.
3. Sheet Metal Thickness for Units 42 through 52 Inches (1060 through 1300 mm) in Diameter: 0.052 inch (1.3 mm) thick.
4. Sheet Metal Thickness for Units 54 through 60 Inches (1370 through 1500 mm) in Diameter: 0.064 inch (1.62 mm) thick.

F. Inner Casing and Baffles: ASTM A 653/A 653M, G90 (Z275) galvanized sheet metal, 0.034 inch (0.85 mm) thick, and with 1/8-inch- (3-mm-) diameter perforations.

G. Special Construction:

1. Suitable for outdoor use.
2. High transmission loss to achieve STC 45.

H. Connection Sizes: Match connecting ductwork unless otherwise indicated.

I. Principal Sound-Absorbing Mechanism:
   1. Controlled impedance membranes and broadly tuned resonators without absorptive media.
   2. Film-lined type with fill material.
      a. Fill Material: Inert, moisture-proof and vermin-proof fibrous material, packed under not less than 15 percent compression
      b. Erosion Barrier: Polymer bag enclosing fill, and heat sealed before assembly.
   3. Lining: Melinex.

J. Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations. Do not use mechanical fasteners for unit assemblies.
   1. Lock form and seal or continuously weld joints.
   2. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
   3. Reinforcement: Cross or trapeze angles for rigid suspension.

K. Accessories:
   1. Factory-installed end caps to prevent contamination during shipping.
   2. Removable splitters.
   3. Airflow measuring devices.

L. Source Quality Control: Test according to ASTM E 477.
   1. Testing of mockups to be witnessed by Engineer/Architect/Owner.
   2. Record acoustic ratings, including dynamic insertion loss and generated-noise power levels with an airflow of at least 2000-fpm (10-m/s) face velocity.
   3. Leak Test: Test units for air tightness at 200 percent of associated fan static pressure or 6-inch wg (1500-Pa) static pressure, whichever is greater.

M. Capacities and Characteristics:

N. Refer to Equipment Schedules.

55.13 TURNING VANES

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting
   1. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.

C. Manufactured Turning Vanes for Nonmetal Ducts: Fabricate curved blades of resin-bonded fiberglass with acrylic polymer coating; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

D. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-3, "Vanes and Vane Runners," and 2-4, "Vane Support in Elbows."

E. Vane Construction: Single wall for ducts up to 48 inches (1200 mm) wide and double wall for larger dimensions.

55.14 REMOTE DAMPER OPERATORS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.:

B. Description: Cable system designed for remote manual damper adjustment.

C. Tubing: Brass.

D. Cable: Stainless steel.

E. Wall-Box Mounting: Surface.

F. Wall-Box Cover-Plate Material: Steel or Stainless steel.

55.15 DUCT-MOUNTED ACCESS DOORS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-10, "Duct Access Doors and Panels," and 2-11, "Access Panels - Round Duct."

1. Door:
    a. Double wall, rectangular.
    b. Galvanized sheet metal with insulation fills and thickness as indicated for duct pressure class.
    c. Vision panel.
    d. Hinges and Latches: 1-by-1-inch (25-by-25-mm) butt or piano hinge and cam latches.
    e. Fabricate doors airtight and suitable for duct pressure class.
2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:
    a. Access Doors Less Than 12 Inches (300 mm) Square: No hinges and two sash locks.
    b. Access Doors up to 18 Inches (460 mm) Square: Two hinges and two sash locks.
    c. Access Doors up to 24 by 48 Inches (600 by 1200 mm): Three hinges and two compression latches with outside and inside handles.
    d. Access Doors Larger Than 24 by 48 Inches (600 by 1200 mm): Four hinges and two compression latches with outside and inside handles.

C. Pressure Relief Access Door:

1. Door and Frame Material: Galvanized sheet steel.
2. Door: Double wall with insulation fill with metal thickness applicable for duct pressure class.
3. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.
4. Factory set at 10-inch wg (2500 Pa).
5. Doors close when pressures are within set-point range.
6. Hinge: Continuous piano.

7. Latches: Cam.
8. Seal: Neoprene or foam rubber.
9. Insulation Fill: 1-inch- (25-mm-) thick, fibrous-glass or polystyrene-foam board.

55.16 DUCT ACCESS PANEL ASSEMBLIES

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Labeled according to UL 1978 by an NRTL.

C. Panel and Frame: Minimum thickness 0.0528-inch (1.3-mm) carbon or 0.0428-inch (1.1-mm) stainless steel.

D. Fasteners: Carbon or Stainless steel. Panel fasteners shall not penetrate duct wall.

E. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F (1093 deg C).

F. Minimum Pressure Rating: 10-inch wg (2500 Pa), positive or negative.

55.17 FLEXIBLE CONNECTORS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Materials: Flame-retardant or noncombustible fabrics.

C. Coatings and Adhesives: Comply with UL 181, Class 1.

D. Metal-Edged Connectors: Factory fabricated with a fabric strip 5-3/4 inches (146 mm) wide attached to 2 strips of 2-3/4-inch- (70-mm-) wide, 0.028-inch- (0.7-mm-) thick, galvanized sheet steel or 0.032-inch- (0.8-mm-) thick aluminum sheets. Provide metal compatible with connected ducts.

E. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 26 oz./sq. yd. (880 g/sq. m).
2. Tensile Strength: 480 lbf/inch (84 N/mm) in the warp and 360 lbf/inch (63 N/mm) in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).

F. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone.

1. Minimum Weight: 24 oz./sq. yd. (810 g/sq. m).
2. Minimum Tensile Strength: 500 lbf/inch (88 N/mm) in the warp and 440 lbf/inch (77 N/mm) in the filling.
3. Service Temperature: Minus 50 to plus 250 deg F (Minus 45 to plus 121 deg C).

G. High-Temperature System, Flexible Connectors: Glass fabric coated with silicone rubber.

1. Minimum Weight: 16 oz./sq. yd. (542 g/sq. m).
2. Tensile Strength: 285 lbf/inch (50 N/mm) in the warp and 185 lbf/inch (32 N/mm) in the filling.
3. Service Temperature: Minus 67 to plus 500 deg F (Minus 55 to plus 260 deg C).

H. High-Corrosive-Environment System, Flexible Connectors: Glass fabric with chemical-resistant coating.

1. Minimum Weight: 14 oz./sq. yd. (474 g/sq. m).

2. Tensile Strength: 450 lbf/inch (79 N/mm) in the warp and 340 lbf/inch (60 N/mm) in the filling.

3. Service Temperature: Minus 67 to plus 500 deg F (Minus 55 to plus 260 deg C).

I. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct.

1. Frame: Steel, fabricated for connection to threaded rods and to allow for a maximum of 30 degrees of angular rod misalignment without binding or reducing isolation efficiency.

2. Outdoor Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.

3. Minimum Additional Travel: 50 percent of the required deflection at rated load.

4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.

7. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch (6-mm) movement at start and stop.

55.18 FLEXIBLE DUCTS

A. Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Retain one of first five paragraphs below for non-insulated, flexible ducts.

C. Non-insulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil.

1. Pressure Rating: 8-inch wg (2280 Pa) positive or negative.

2. Maximum Air Velocity: 5000 fpm (25 m/s).

3. Temperature Range: Minus 100 to plus 435 deg F (Minus 73 to plus 224 deg C).

D. Insulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil; fibrous-glass insulation; aluminized vapor-barrier film.

1. Pressure Rating: 8-inch wg (2280 Pa) positive or negative.

2. Maximum Air Velocity: 5000 fpm (25 m/s).

3. Temperature Range: Minus 20 to plus 250 deg F (Minus 29 to plus 121 deg C).

4. Insulation R-value: Comply with ASHRAE/IESNA 90.1-2004.

E. Flexible Duct Connectors:

1. Clamps: Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action in sizes 3 through 18 inches (75 through 460 mm), to suit duct size.

55.19 DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 56 - EXECUTION

56.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Install backdraft or control dampers (as identified on the drawings) at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.

1. Install steel volume dampers in steel ducts.
2. Install aluminum volume dampers in aluminum ducts.

E. Set dampers to fully open position before testing, adjusting, and balancing.

F. Install test holes at fan inlets and outlets and elsewhere as indicated.

G. Install fire and smoke dampers according to UL listing.

H. Connect ducts to duct silencers rigidly.

I. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. On both sides of duct coils.
2. Upstream and downstream from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
7. At each change in direction and at maximum 50-foot (15-m) spacing.
8. Upstream and downstream from turning vanes.
9. Upstream or downstream from duct silencers.
10. Control devices requiring inspection.
11. Elsewhere as indicated.

J. Install access doors with swing against duct static pressure.

K. Access Door Sizes:

1. One-Hand or Inspection Access: 8 by 5 inches (200 by 125 mm).
2. Two-Hand Access: 12 by 6 inches (300 by 150 mm).

3. Head and Hand Access: 18 by 10 inches (460 by 250 mm).
4. Head and Shoulders Access: 21 by 14 inches (530 by 355 mm).
5. Body Access: 25 by 14 inches (635 by 355 mm).
6. Body plus Ladder Access: 25 by 17 inches (635 by 430 mm).

L. Label access doors according to Division 23 Section "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

M. Install flexible connectors to connect ducts to equipment.

N. For fans developing static pressures of 5-inch wg (1250 Pa) and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

O. Connect terminal units to supply ducts with maximum 24-inch (600-mm) lengths of flexible duct. Do not use flexible ducts to change directions.

P. Connect diffusers or light troffer boots to ducts with maximum 60-inch (1500-mm) lengths of flexible duct clamped or strapped in place.

Q. Connect flexible ducts to metal ducts with draw bands.

R. Install duct test holes where required for testing and balancing purposes.

S. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch (6-mm) movement during start and stop of fans.

56.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.
5. Operate remote damper operators to verify full range of movement of operator and damper.

XXII. AXIAL HVAC FANS

PART 57 - GENERAL

57.1 RELATED DOCUMENTS

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

57.2 SUMMARY

A. This Section includes the following:

1. Tube axial fans.
2. Vane axial fans.
3. Smoke Extract Fans.

57.3 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan performance ratings on actual Project site elevations above sea level.

B. Operating Limits: Classify according to AMCA 99.

57.4 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:

1. Certified fan performance curves with system operating conditions indicated.
2. Certified fan sound-power ratings.
3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
4. Material thickness and finishes, including color charts.
5. Dampers, including housings, linkages, and operators.
6. Fan speed controllers.

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

1. Wiring Diagrams: Power, signal, and control wiring.
2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
3. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

C. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

D. Field quality-control test reports.

E. Operation and Maintenance Data: For axial fans to include in emergency, operation, and maintenance manuals.

57.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA Certified Ratings Seal.

C. NEMA Compliance: Motors and electrical accessories shall comply with NEMA or equivalent BS standards.

D. All fans to be UL listed FM approved. Life safety fans further shall be approved and listed by the local authority having jurisdiction.

57.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations, with protective crating and covering.

B. Disassemble and reassemble units, as required for moving to final locations, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

57.7 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

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

57.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Belts: One set for each belt-driven unit.

PART 58 - PRODUCTS

58.1 TUBE-AXIAL FANS

A. Manufacturers: Subject to compliance with requirements, provide from the list of approved manufacturers

B. Description: Fan wheel and housing, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.

C. Housings: Galvanized steel with flanged inlet and outlet connections.

D. Wheel Assemblies: Cast or extruded aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.

E. Drives: Factory mounted, with final alignment and belt adjustment made after installation.

1. Service Factor Based on Fan Motor Size: 1.2.
2. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
3. Fan Pulleys: Cast iron with split tapered bushing; dynamically balanced at factory.
4. Motor Pulleys: Adjustable pitch for use with motors through 5 HP; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, non-sparking, and non-static; matched sets for multiple belt drives.
6. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
7. Motor Mount: Adjustable base.
8. Shaft Bearings: Radial, self-aligning ball bearings.
    a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
    b. Extend lubrication lines to outside of casing and terminate with grease fittings.

F. Accessories:

1. Companion Flanges: Rolled flanges of same material as housing.
2. Mounting Clips: Horizontal ceiling/Vertical mounting clips welded to fan housing, of same material as housing.
3. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
4. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.
5. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
6. Back draft Dampers: Butterfly style, for bolting to the discharge of fan or outlet cone, of same material as housing.
7. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to 149 deg C.
8. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
9. Inlet Cones: Round-to-round transition of same material as housing.

G. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Totally enclosed, fan cooled.
2. Direct-Driven Units: Encase motor in housing outside of airstream.

H. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: Hot-dip galvanized.
    a. Apply to finished housings.
    b. Apply to fan wheels.
4. Vibration Isolators: Restrained spring isolators having a static deflection of 25mm.

58.2 VANEAXIAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products from the list of approved manufacturers.

B. Description: Fan wheel and housing, straightening vane section, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.

C. Housings: Galvanized steel.
1. Inlet and Outlet Connections: Flanges.
2. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.

D. Wheel Assemblies: Cast-aluminium hub assembly, machined and fitted with threaded bearing wells to receive blade-bearing assemblies with replaceable, cast-aluminum blades; factory mounted and balanced.

E. Drives: Factory mounted, with final alignment and belt adjustment made after installation.
1. Service Factor Based on Fan Motor Size: 1.2.
2. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
3. Fan Pulleys: Cast iron with split tapered bushing; dynamically balanced at factory.
4. Motor Pulleys: Adjustable pitch for use with motors through 5HP; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
5. Belts: Oil resistant, non-sparking, and non-static; matched sets for multiple belt drives.
6. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
7. Motor Mount: Adjustable base.
8. Shaft Bearings: Radial, self-aligning ball or roller bearings.
    a. Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
    b. Extend lubrication lines to outside of casing and terminate with grease fittings.

F. Accessories:
1. Companion Flanges: Rolled flanges of same material as housing.
2. Propeller Access Section Door: Short duct section bolted to fan inlet/outlet allowing access to internal parts of fan for inspection and cleaning, of same material as housing.
3. Mounting Clips: Horizontal ceiling/Vertical mounting clips welded to fan housing, of same material as housing.
4. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
5. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.

6. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork of same material as housing.
7. Back draft Dampers: Butterfly style, for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section of same material as housing.
8. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up 148 deg C.
9. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
10. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation of same material as housing.
11. Inlet Cones: Round-to-round transition of same material as housing.

G. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
1. Enclosure Type: Totally enclosed, fan cooled.
2. Direct-Driven Units: Encase motor in housing outside of airstream.

H. Factory Finishes:
1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.
3. Coatings: Hot-dip galvanized.
a. Apply to finished housings.
b. Apply to fan wheels.

I. Vibration Isolators: Restrained spring isolators having a static deflection of 25 mm.

58.3 SMOKE EXTRACT FANS

A. Smoke extract fan units shall be capable of extracting smoke at a temperature for 400°C for a minimum of 120 minutes.

B. Smoke extract fan units shall be suitable for roof or indoor mounting with the extracted gasses being discharged vertically or horizontally via the air operated/gravity return shutters.

C. The smoke extract fan units shall have a unit case manufactured in aluminum alloy or polyester painted zinc coated steel. Non rusting fixings shall be used throughout.

D. Bird guards shall be provided which shall automatically be displaced in the event of fire debris blocking the airway.

E. Each unit shall have a high-performance axial flow impeller, balanced and dynamically checked to ensure smooth even running.

F. Electrical input connections shall be provided by a connector box mounted on the outside of the unit and powered to the motor with heat resisting cable.

G. Fan units shall be fitted with internally mounted electrical isolators fitted behind a guide release panel.

58.4 SOURCE QUALITY CONTROL

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

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

C. The fans shall not be selected at the top of the P/V curve, the selection shall be made at the most stable portion of the capacity range in the region of 2/3rd up the curve. Fans and shafts shall operate well below the first critical speed.

D. Fan outlet velocities to be in accordance with ASHRAE recommendations and preferably less than 10m/s.

E. Select fans to meet the noise criteria of the surrounding spaces. Attenuators, required for meeting noise criteria may be provided at no additional cost.

PART 59 - EXECUTION

59.1 INSTALLATION

A. Install axial fans level and plumb.

B. Support floor-mounting units using restrained spring isolators having a static deflection of 25mm. Vibration- and seismic-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

C. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

D. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-Place Concrete."

E. Support suspended units from structure using threaded steel rods and spring hangers with vertical-limit stops having a static deflection of 25mm. Vibration-control devices are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

F. Install units with clearances for service and maintenance.

G. Label fans according to requirements specified in Division 23 Section "Identification for HVAC Piping and Equipment."

59.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories."

B. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

C. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

D. Provide fire rated flexible sleeves on discharge and ducted suction connectors of all fans made with heavy quality glass-fiber reinforced canvas having a minimum length of 150mm securely fixed and sealed to minimize air leakage having a maximum flame spread rating of 25.

E. For smoke extract applications the flexible duct connections shall be suitable for the temperature and nature of gases associated with the type of application whilst retaining the flexibility of the material.

59.3 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connection to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that cleaning and adjusting are complete.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
5. Adjust belt tension.
6. Adjust damper linkages for proper damper operation.
7. Verify lubrication for bearings and other moving parts.

8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

9. Disable automatic temperature-control operators, energize motor and confirm proper motor rotation and unit operation, adjust fan to indicated rpm, and measure and record motor voltage and amperage.

10. Shut unit down and reconnect automatic temperature-control operators.

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

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

59.4 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Lubricate bearings.

XXIII. AIR TERMINAL UNITS

PART 60 - GENERAL

60.1 RELATED DOCUMENTS

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

60.2 SUMMARY

A. Section Includes:

1. Shutoff, single-duct air terminal units.

60.3 PERFORMANCE REQUIREMENTS

A. Structural Performance: Hangers and supports and seismic restraints shall withstand the effects of gravity and seismic loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible".

60.4 SUBMITTALS

A. Product Data: For each type of the following products, including rated capacities, furnished specialties, sound-power ratings, and accessories.

1. Air terminal units.
2. Liners and adhesives.
3. Sealants and gaskets.
4. Seismic-restraint devices.

B. LEED Submittal:

1. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2004, Section 5 - "Systems and Equipment."

C. Shop Drawings: For air terminal units, include plans, elevations, sections, details and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal and control wiring.
3. Hangers and supports, including methods for duct and building attachment, seismic restraints and vibration isolation.

D. Delegated-Design Submittal:

1. Materials, fabrication, assembly, and spacing of hangers and supports.
2. Design Calculations: Calculations for selecting hangers and supports and seismic restraints.

E. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Ceiling suspension assembly members.
2. Size and location of initial access modules for acoustic tile.
3. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels and special moldings.

F. Field quality-control reports.

G. Operation and Maintenance Data: For air terminal units to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include the following:

1. Instructions for resetting minimum and maximum air volumes.
2. Instructions for adjusting software set points.

60.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labelled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2004, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

60.6 EXTRA MATERIALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fan-Powered-Unit Filters: Furnish one spare filter for each filter installed.

PART 61 - PRODUCTS

61.1 SHUTOFF, SINGLE-DUCT AIR TERMINAL UNITS

A. Manufacturers: Subject to compliance with requirements, provide products from the approved list of manufacturers.

B. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.

C. Casing: 0.85-mm galvanized steel double wall construction.

1. Casing Lining: Adhesive attached 25-mm thick, polyurethane foam insulation, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
2. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections, size matching inlet size.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2007.

D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Maximum Damper Leakage: ARI 880 rated, 2 percent of nominal airflow at 750Pa inlet static pressure.
2. Damper Position: Normally closed.

E. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation and Control for HVAC" and shall have the following features:

1. Damper Actuator: 24 V, powered closed, spring return open
2. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 1000 Pa; and shall have a multipoint velocity sensor at air inlet.
3. Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.

F. Control Sequence:

1. Suitable for operation with duct pressures between 60- and 750 Pa inlet static pressure.
2. System-powered, wall-mounted thermostat.

61.2 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electro galvanized all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

D. Air Terminal Unit Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

E. Trapeze and Riser Supports: Steel shapes and plates for units with steel casings; aluminum for units with aluminum casings.

61.3 SEISMIC-RESTRAINT DEVICES

A. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an agency acceptable to authorities having jurisdiction.

1. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.

B. Channel Support System: Shop or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.

C. Hanger Rod Stiffener: steel slotted-support system with internally bolted connections to hanger rod.

D. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

61.4 SOURCE QUALITY CONTROL

A. Factory Tests: Test assembled and calibrated air terminal units according to ARI 880. Tests and calibration to be witnessed by the Engineer.

1. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, and ARI certification seal along with calibration certificate.

PART 62 - EXECUTION

62.1 INSTALLATION

A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

B. Provide three (3) inlet duct diameters of straight duct run upstream of terminal units.

C. Install air terminal unit level. Maintain sufficient clearance for normal service and maintenance. For ceiling access to units, provide access doors or locate above easily removable ceiling components.

D. Install wall-mounted thermostats.

62.2 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 100 mm thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 100 mm thick.
5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hangers Exposed to View: Threaded rod and channel supports.

D. Support units individually from the structure. Do not support from adjacent ductwork. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

62.3 SEISMIC-RESTRAINT-DEVICE INSTALLATION

A. Install hangers and braces designed to support the air terminal units and to restrain against seismic forces required by applicable building codes. Comply with SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems.

B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.

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

D. Install cable restraints on air terminal units that are suspended with vibration isolators.

E. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction.

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

G. Drilling for and Setting Anchors:

1. Identify position of reinforcing steel and other embedded items before drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling.

Locate and avoid pre stressed tendons, electrical and telecommunications conduit, and gas lines.

2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Install heavy-duty sleeve anchors with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Set anchors to manufacturer's recommended torque, using a torque wrench.
5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

62.4 CONNECTIONS

A. Installation to allow service and maintenance.

B. Connect ducts to air terminal units according to Division 23 Section "Metal Ducts."

C. Coordinate duct installations and specialty arrangements with Drawings.

D. Make connections to air terminal units with flexible connectors complying with requirements in Division 23 Section "Air Duct Accessories."

62.5 IDENTIFICATION

A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Division 23 Section "Identification for HVAC Piping and Equipment" for equipment labels and warning signs and labels.

62.6 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Air terminal unit will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

62.7 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.
2. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
3. Verify that controls and control enclosure are accessible.
4. Verify that control connections are complete.
5. Verify that nameplate and identification tag are visible.

6. Verify that controls respond to inputs as specified.

62.8 DEMONSTRATION

A. Engage a factory authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air terminal units.

XXIV. DIFFUSERS, REGISTERS AND GRILLS

PART 63 - GENERAL

63.1 RELATED DOCUMENTS

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

63.2 SUMMARY

A. Section Includes:

1. Round ceiling diffusers.
2. Rectangular and square ceiling diffusers.
3. Linear bar diffusers.
4. Linear slot diffusers.
5. Adjustable bar registers and grilles.
6. Linear bar grilles.
7. Intake and Exhaust Air Louvers

B. Related Sections:

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

63.3 SUBMITTALS

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

1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
2. Diffuser, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

B. Samples for Initial Selection: For diffusers, registers, and grilles with factory-applied color finishes.

C. Samples for Verification: For diffusers, registers, and grilles, in manufacturer's standard sizes to verify color selected.

D. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Ceiling suspension assembly members.
2. Method of attaching hangers to building structure.
3. Size and location of initial access modules for acoustical tile.
4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
5. Duct access panels.

E. All grills and diffusers shall be selected to comply with noise level as specified elsewhere. Selection shall be based on Maximum (25 – 27) NC levels.

F. Source quality-control

1. Test and rate performance of air outlets and inlets in accordance with ADC Equipment Test Code 1062 and ASHRAE 70,

2. Test and rate performance of louvers in accordance with AMCA 500.
3. Provide air outlets and inlets bearing ADC certified rating seal.

PART 64 - PRODUCTS

64.1 CEILING DIFFUSERS

A. Round Ceiling Diffuser

1. Manufacturers: Subject to compliance with requirements, provide from the approved Pattern: Fully adjustable.
2. list of Manufacturer's.
3. Devices shall be compatible with variable-air-volume flows.
4. Material: Aluminum.
5. Finish: Powder coated; color selected by Architect.
6. Mounting: Duct connection, concealed.
7. Dampers: Radial opposed blade with removable key operator, operable from face

B. Rectangular and Square Ceiling Diffusers

1. Manufacturers: Subject to compliance with requirements, provide from the list of approved manufacturers:
2. Devices shall be compatible with variable-air-volume flows.
3. Material: Aluminum.
4. Finish: Powder coated; color selected by Architect.
5. Pattern: Adjustable.
6. Dampers: Radial opposed blade with removable key operator, operable from face.

64.2 CEILING LINEAR SLOT OUTLETS

A. Linear Bar Diffuser:

1. Manufacturers: Subject to compliance with requirements, provide from the approved list of manufacturers.
2. Devices shall be compatible with variable-air-volume flows.
3. Material: Aluminum.
4. Finish: Powder coated; color selected by Architect
5. Pencil-Proof Core Spacing Arrangement: 5-mm thick blades spaced 11 mm apart, zero/ 15/30 degree deflection.
6. Extruded construction fixed louvers with removable core.
7. Frame: 32 mm wide.
8. Mounting: Concealed.
9. Damper Type: Adjustable opposed-blade assembly with removable key operator, operable from face.

B. Linear Slot Diffuser

1. Manufacturers: Subject to compliance with requirements, provide from the approved list of manufacturers.
2. Devices shall be compatible with variable-air-volume flows.
3. Material - Shell: Aluminum
4. Material - Pattern Controller and Tees: Aluminum.
5. Finish - Face and Shell: Powder coated; color selected by Architect.

6. Slot Width. As per drawings mm.

7. Number of Slots: Two/Three, as per drawings.

64.3 REGISTERS AND GRILLES

A. Adjustable Bar Register:

1. Manufacturers: Subject to compliance with requirements, provide from list of approved manufacturers.
2. Material: Aluminum.
3. Finish: Powder coated color as required by architect.
4. Core Construction: Removable.
5. Frame: 32 mm wide.
6. Mounting: Concealed.
7. Damper Type: Adjustable opposed blade with removable key operator, operable from face.

B. Adjustable Bar Grille

1. Manufacturers: Subject to compliance with requirements, provide from the list of approved lists of manufacturers.
2. Material: Aluminum.
3. Finish: Powder coated; color as required by architect
4. Core Construction: Removable.
5. Frame: 32 mm wide.
6. Mounting: Concealed.

64.4 JET NOZZELS

1. Manufacturers: Subject to compliance with requirements, provide from the list of approved lists of manufacturers.
2. Material: Aluminum.
3. Finish: Powder coated; color as required by architect
4. Mounting: Panel is concealed and nozzles are exposed
5. The core of the outlet shall be rotatable so as to deliver air in a jet pattern or in a diffused pattern.
6. The throw of the diffused pattern shall be approximately half that of the jet pattern at similar terminal velocities. Jet type diffusers without spread capability are not acceptable
7. In either position, the axis of air flow may be varied up to 30° from the straight-forward in a full 360° arc.
8. The outlet shall be attached to a mounting panel with mounting screws permitting 360° rotation. Up to four outlets may be attached to one mounting panel permitting multi-directional, as well as mixed jet and diffused patterns, from one location.

64.5 DISK VALVES

1. Manufacturers: Subject to compliance with requirements, provide from the list of approved lists of manufacturers.
2. Material: Aluminum.
3. Finish: Powder coated; color as required by architect

4. This disc valves consist of the valve ring and central disc.
5. To guarantee a perfect seat, the valve ring is fitted with a peripheral sealing strip.
6. The air volume flow rate is adjusted by rotating the central disc which alters the size of the gap. The central disc is held in position with a locknut.

B. Extract And Fresh Air Louvers

1. All fresh air Intake louvers shall be aluminium construction with standard finish, Fresh air louvers shall be sand trap type with minimum 30% free Area.
2. Fresh Air louvers shall be fitted with a galvanized steel bird screen mesh, and shall be self-emptying type to discharge separated sand particle
3. Extract air louvers shall be aluminum construction with standard finish and colour as per architectural requirement, shall have a minimum 50% free area, shall be weather proof suitable for external walls, shall provide visual screening, and protection against rain water.

64.6 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate diffusers, registers, and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 65 - EXECUTION

65.1 EXAMINATION

A. Examine areas where diffusers, registers, and grilles are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

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

65.2 INSTALLATION

A. Install diffusers, registers, and grilles level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

65.3 ADJUSTING

A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

xxv. PARTICULATE AIR FILTRATION

PART 66 - GENERAL

66.1 RELATED DOCUMENTS

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

66.2 SUMMARY

A. Section Includes:

1. Type 1 Filters - Panel type for specified Split System Air Conditioning Unit, Fan Coil Unit & Duct-Mounted Filters

2. Type 2 filters - Panel type for specified Duct-Mounted Filters

3. Type 3 filters - Deep bed type for specified Air Handling Units

66.3 SUBMITTALS

A. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.

B. Shop Drawings: For air filters include plans, elevations, sections, details, and attachments to other work.

1. Show filter rack assembly, dimensions, materials, and methods of assembly of components.

2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.

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

C. Operation and Maintenance Data: For each type of filter and rack to include in emergency, operation, and maintenance manuals.

D. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

66.4 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASHRAE Compliance:

1. Comply with applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality"; Section 5 - "Systems and Equipment"; and Section 7 - "Construction and Startup."

2. Comply with ASHRAE 52.1 for arrestance and ASHRAE 52.2 for MERV for methods of testing and rating air-filter units.

C. Comply with NFPA 90A and NFPA 90B.

66.5 COORDINATION

A. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases.

66.6 EXTRA MATERIALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Provide one complete set of filters for each filter bank. If system includes prefilters, provide only prefilters.
2. Provide one container of red oil for inclined manometer filter gauge.

PART 67 - PRODUCTS

67.1 TYPE 1 FILTERS - PANEL TYPE FOR SPECIFIED SPLIT SYSTEM AIR CONDITIONING UNIT, FAN COIL UNIT & DUCT-MOUNTED FILTERS

A. Available Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Filters shall be nominal 12 mm deep washable dry media, aluminium or equivalent corrosion resistant framed, panel filters.

C. The frame shall be designed to slide into standard 12.7 mm channels to minimise air bypass.

D. Media: Interlaced glass or synthetic fibers or cotton and synthetic fibers coated with nonflammable adhesive.

1. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Media shall be coated with an antimicrobial agent.
3. Separators shall be bonded to the media to maintain pleat configuration.
4. Welded wire grid shall be on downstream side to maintain pleat.
5. Media shall be bonded to frame to prevent air bypass.
6. Support members on upstream and downstream sides to maintain pleat spacing.

E. Filters shall achieve the following criteria when handling the design air quantity:

1. Initial resistance not greater than 20 Pa.
2. Filter face velocity not greater than 1.8 m/s.
3. Minimum average arrestance 63% (ASHRAE 52.1,1992 or AS1132, Dust No. 4) or G2 (EN 779).
4. Minimum dust holding capacity at 125 Pa: 350 g per square metre of filter media.
5. Final resistance: 125 Pa (Final resistances specified on the Drawings are solely for the purposes of fan pressure calculations).

67.2 TYPE 2 FILTERS - PANEL TYPE FOR SPECIFIED DUCT-MOUNTED FILTERS

A. Available Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Filters shall be washable dry media, aluminium or equivalent corrosion-resistant framed, panel filters. The media shall be sealed effectively to the filter frame.

C. Sliding-type filter frames shall be either nominally 12 mm or 25 mm deep. Holding-type filter frames shall be two-piece, nominally 25 mm deep. The holding/sliding frame shall be designed to minimize air bypass when installed.

D. Media: Interlaced glass or synthetic fibers or cotton and synthetic fibers coated with nonflammable adhesive.

1. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Media shall be coated with an antimicrobial agent.
3. Separators shall be bonded to the media to maintain pleat configuration.
4. Welded wire grid shall be on downstream side to maintain pleat.
5. Media shall be bonded to frame to prevent air bypass.
6. Support members on upstream and downstream sides to maintain pleat spacing.

E. Filter banks shall achieve the following criteria when handling the design air quantity:

1. Initial resistance not greater than 40 Pa at the actual duct, or louvre velocity (not greater than 2.5 m/s).
2. Minimum average arrestance 63% (ASHRAE 52.1, 1992 or AS1132, Dust No. 4) or G2 (EN 779).
3. Minimum dust holding capacity at 125 Pa: 350 g per square meter of filter media.
4. Final resistance: 125 Pa.

67.3 TYPE 3 FILTERS - DEEP BED TYPE FOR SPECIFIED AIR HANDLING UNITS

A. Available Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. In line with client requirements the FAHU filter section should be made up of a rough filter, as described below, and a fine filter (High Efficiency Bag Filter).

C. Filters shall be extended surface disposable dry media self-supporting wedge-shaped pocket type (ie. without wire media supports). The filter media shall be sealed effectively to the filter frame.

D. Filters shall be supplied complete with a two-piece stainless steel or equivalent corrosion resistant holding frame. The holding frame shall have appropriately durable sealing surfaces to minimize air bypass when installed.

E. Media: Interlaced glass or synthetic fibers or cotton and synthetic fibers coated with nonflammable adhesive.

1. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Media shall be coated with an antimicrobial agent.
3. Separators shall be bonded to the media to maintain pleat configuration.
4. Welded wire grid shall be on downstream side to maintain pleat.
5. Media shall be bonded to frame to prevent air bypass.
6. Support members on upstream and downstream sides to maintain pleat spacing.

F. Filter banks shall achieve the following criteria when handling the design air quantity:

1. Initial resistance not greater than 60 Pa, measured across the filter bank as installed (ie. including the effect of any surrounding blanking plate).
2. Filter bank face velocity not greater than 2.5 m/s.
3. Minimum average efficiency 40% (ASHRAE 52.1, 1992 or AS1132, Dust No. 1) or F5 (EN 779).
4. Minimum dust holding capacity at 125 Pa: 200 g per 600 mm square module.
5. Final resistance: 125 Pa.

PART 68 - EXECUTION

68.1 INSTALLATION

A. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.

B. Install filters in position to prevent passage of unfiltered air.

C. Install filter gauge for each filter bank.

D. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.

E. Install filter-gauge, static-pressure taps upstream and downstream from filters. Install filter gauges on filter banks with separate static-pressure taps upstream and downstream from filters. Mount filter gauges on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gauges.

F. Coordinate filter installations with duct and air-handling-unit installations.

68.2 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

B. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

C. Tests and Inspections:

1. Operate automatic roll filters to demonstrate compliance with requirements.

2. Test for leakage of unfiltered air while system is operating.

D. Air filter will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

68.3 CLEANING

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

XXVI. ENERGY METER

GENERAL

69.1 MEASURED VARIABLE

A. Flow velocity (proportional to induced voltage)

B. Measuring ranges

1. Measuring ranges Typically v = 0.01 to 10 m/s (0.03 to 33ft/s) with the specified accuracy

C. Operable flow range

1. Over 1000:1

69.2 STATUS INPUT (AUXILIARY INPUT)

A. U = 3 to 30 V DC, Ri = 5 kΩ, galvanically isolated

B. Configurable for : totalizer (s) reset, measured value suppression, error-message reset

69.3 STATUS INPUT (AUXILIARY INPUT) WITH PROFIBUS DP AND MODBUS RS485

A. U=3 to 30 V DC, R1 = 3 kΩ, galvanically isolated

B. Switching level: 3 to 30 V DC, independent of polarity

C. Configurable for: totalizer (s) reset, measured value suppression, error-message reset, batching start/stop (optional), batch totalizer reset (optional)

69.4 CURRENT INPUT

A. Active/passive selectable, galvanically isolated, full scale value selectable, resolution: 3 μA, temperature coefficient: typ. 0.005% o.r/^{0}C (o.r. = of reading)

1. Active: 4 to 20 mA, Ri ≤150Ω, max. 24 V DC, short-circuit-proof

2. Passive: 0/4 to 20 mA, Ri <150Ω, max. 30 V DC

69.5 CURRENT OUTPUT

A. Active/passive selectable, galvanically isolated, time constant selectable (0.01 to 100 s), full scale value

1. Active: 0/4 to 20 mA, RL <700 Ω (HART: RL ≥250 Ω)

2. Passive: 4 to 20 mA, operating voltage VS : 18 to 30 V DC Ri ≥150 Ω

69.6 PULSE/FREQUENCY OUTPUT

A. Passive, open collector, 30 V DC, 250 mA, galvanically isolated

69.7 CURRENT OUTPUT

A. Active/passive selectable, galvanically isolated, time constant selectable (0.01 to 100 s), full scale value selectable, temperature coefficient: typ. 0.005% o.r/^{0}C (o.r. = of reading), resolution: 0.5μ A

1. Active: 0/4 to 20mA, RL <700Ω (HART: RL ≥250 Ω

2. Passive: 4 to 20 mA, operating voltage VS: 18 to 30 V DC, RL ≥150 Ω

69.8 PULSE/FREQUENCY OUTPUT

A. Active/passive selectable, galvanically isolated (Ex I version: only passive)

1. Active: 24 V DC, 25 mA (max. 250 mA during 20 ms), RL > 100 Ω

2. Passive: open collector, 30 V DC, 250mA

3. Frequency output: full scale frequency 2 to 10000Hz (fmax = 12500Hz) EEx-ia:2 to 500Hz; on/off ratio 1:1, pulse width mas. 10s

4. Pulse output: pulse value and pulse polarity selectable, max. pulse width configurable (0.05 to 200 ms)

69.9 PROFIBUS DP INTERFACE

A. Transmission technology (Physical Layer): RS485 in accordance with ANSI/TIA/EIA-485-A:1998, galvanically isolated

1. Profile version 3.0
2. Data transmission rate: 9,6 kBaud to 12 MBaud
3. Automatic data transmission rate recognition
4. Function blocks: 2 x analog Input, 3 x totalizer
5. Output data: volume flow, calculated mass flow, totalizer 1 to 3
6. Input data: positive zero return (ON/OFF), totalizer control, value for local display
7. Bus address adjustable via miniature switches or local display (optional) at the measuring device

69.10 PROFIBUS PA INTERFACE

A. Transmission technology (Physical Layer): IEC 61158-2 (MBP), galvanically isolated

1. Profile version 3.0
2. Current consumption: 11 mA
3. Permissible supply voltage: 9 to 32 V
4. Bus connection with integrated reverse polarity protection
5. Error current FDE (Fault Disconnection Electronic): 0 mA
6. Function blocks: 2 x analog input, 3 x totalizer
7. Output data: positive zero return (ON/OFF), control totalizer, value for local display
8. Bus address adjustable via miniature switches or local display (optional) at the measuring device.

69.11 MODBUS RS485 INTERFACE

A. Transmission technology (Physical Layer): RS485 in accordance with ANSI/TIA/EIA-485- A:1998, galvanically isolated

1. MODBUS device type: slave
2. Address range: 1 to 247
3. Bus address adjustable via miniature switches or local display (optional) at the measuring device
4. Supported MODBUS function codes: 03, 04, 06, 08, 16, 23
5. Broadcast: supported with the function codes 06, 16, 23
6. UbertragungsmodusL RTU order ASCII
7. Supported baudrate: 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200 Baud
8. Response time:
9. direct data access = typically 25 to 50ms
10. auto-scan buffer (data range) = typically 3 to 5 ms

69.12 FOUNDATION FIELDBUS INTERFACE

A. FOUNDATION Fieldbu H1

B. Transmission technology (Physical Layer): IEC 61158-2 (MBP), galvanically isolated

C. ITK version 5.01

D. Current consumption: 12mA

E. Error current FDE (Fault Disconnection Electronic): 0 mA

F. Bus connection with integrated reverse polarity protection

G. Function blocks:

1. 5 x Analog Input (execution time: 18ms each)
2. 1 x PID (25 ms)
3. 1 x Digital Output (18 ms)
4. 1 x Signal Characterizer (20 ms)
5. 1 x Input Selector (20 ms)
6. 1 x Arithmetic (20 ms)
7. 1 x Integrator (18 ms)

H. Output data: volume flow, calculated mass flow, temperature, totalizer 1 to 3

I. Input data: positive zero return (ON/OFF), reset totalizer

J. Link Master (LM) functionality is supported

69.13 SIGNAL ON ALARM

A. Current output failure response selectable (e.g in accordance with NAMUR recommendation NE 43)

B. Pulse/frequency output □□ failure response selectable

C. Status output □□ non-conductive by fault or power supply failure

D. Relay output □□ de-energized by fault or power supply failure

69.14 LOAD

A. See “Output signal”

69.15 LOW FLOW CUTOFF

A. Switch points for low flow cutoff are selectable

69.16 GALVANIC ISOLATION

A. All circuits for inputs, outputs and power supply are galvanically isolated from each other

69.17 SWITCHING OUTPUT

A. Status output

B. Open collector, max. 30 V DC/250 mA, galvanically isolated

C. Configurable for: error messages. Empty Pipe

D. Detection (EPD), flow direction, limit values

E. Relay output

PART 70 - PRODUCTS

70.1 MATERIAL

A. Transmitter housing

1. Compact housing: powder-coated die-cast aluminum
2. Wall-mount housing: powder-coated die- cast aluminum

B. Sensor housing

1. DN 25 to 300 (1 to 12”): powder-coated die-cast aluminum
2. DN 350 to 600 (14 to 24”): with protective lacquering

C. Measuring tube

1. DN ≤300 (12”): stainless steel 1.4301 or 1.4306/304L; (for flanges made of carbon steel with A1/Zn protective coating)
2. DN ≤300 (12”): stainless steel 1.4301 or 1.4306/304L; (for flanges made of carbon steel with protective lacquering)
3. Electrode: 1.4435, Platinum, Alloy C-22,
4. Tantalum, Titanium

D. Flanges

1. EN 1092-1 (DIN 2501): 1.4571/316L; RSt37-1 (S235JRG2); C22; FE 410W B (DN ≤300 (12”): with A1/Zn protective coating; DN ≥350 (14”) with protective lacquering)
2. ANSI: A105; F316L (DN ≤300 (12”): with A1/Zn protective coating; DN ≥350 (14”) with protective lacquering)
3. AWWA: 1.0425
4. JIS: RSt37-2 (S235JRG2); HII;
5. 1.0425/316L (DN ≤300 (12”): with A1/Zn protective coating; DN ≥350 (14”) with protective lacquering)
6. AS 2129
7. DN 25 (1”): A105 or RSt37-2 (S235JRG2)
8. DN 40 (1½”): A105 or St44-2 (S275JR)
9. AS 4087: A105 or St44-2 (S275JR)
10. Seals: to DIN EN 1514-1
11. Ground disk: 1.4435/316L or Alloy C-22

70.2 MEASURING SYSTEM

A. The measuring system consists of a transmitter and a sensor.

70.3 SIZE

A. DN 15 to 600 (from ½ to 24”)

XXVII. PLATE AND FRAME HEAT EXCHANGERS

PART 71 - GENERAL

71.1 RELATED DOCUMENTS

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

B. Specifications throughout all Divisions of the Project Manual are directly applicable to this Section, and this Section is directly applicable to them.

71.2 SUMMARY

A. Perform all Work required to provide and install plate and frame heat exchangers, accessories and trim indicated by the Contract Documents with supplementary items necessary for proper installation and operation.

71.3 REFERENCE STANDARDS

A. References:

1. ASME Section II – Material Specification
2. ASME Section V – Non-Destructive Testing
3. ASME Section IX – Welding and Brazing Qualifications
4. ASME – Pressure Vessel Code
5. ARI Standard 400 – Liquid to Liquid Heat Exchangers
6. PED Compliance: Fabricate and label heat exchangers to comply with PED European pressure Vessel Codes.

B. The latest published edition of a reference shall be applicable to this Project unless identified by a specific edition date.

C. All reference amendments adopted prior to the effective date of this Contract shall be applicable to this Project.

D. All materials, installation and workmanship shall comply with the applicable requirements and standards addressed within all references.

71.4 QUALITY ASSURANCE

A. The plate heat exchanger manufacturer shall have an established and on-going QA/QC program including manuals available for inspection at the plant.

B. The plate and frame heat exchanger manufacturer shall have an extensive background and experience in the design and fabrication of plate heat exchangers. The manufacturer shall have fabricated plate heat exchangers for a minimum of ten (10) years.

1. ARI Certification:

   a. Plate heat exchanger shall be certified according to ARI Standard 400 and listed on the ARI Prime Net site (www.ariprimenet.org). If heat exchanger is not ARI certified, then the manufacturer shall provide an independent third-party field performance test using mapped ratings and tolerances of ARI Standard 400 to verify performance to specification. Any and all cost associated with correcting a non-performing heat exchanger to meet performance requirements shall be the responsibility of the supplier. Any cost associated with the field performance test shall be included in the price of the heat exchanger.

b. [Alternate for non-certified ARI exchangers: If exchanger is not ARI certified, then the manufacturer shall provide 110% of the heat transfer area of an ARI certified heat exchanger and provide written verification of performance to the specification. Any and all cost associated with correcting a non-performing heat exchanger to meet the performance requirements shall be the responsibility of the supplier.]

2. ASME Certification:

a. The complete assembly shall be factory assembled and tested in accordance with ASME Code, Section VIII, and Division I, and furnished with ASME Code Certification (VI Form) for design pressures as specified in this Section.

71.5 SUBMITTALS

A. Product Data and Record Documents:

1. Submit Shop Drawings and product data for manufactured products and assemblies.

2. Indicate empty and operating weights, frame length, height, plate width, and clearance dimension requirements, locations and size and rating of flanged connections. Provide certified performance data heat exchanger hot and cold inlet and outlet water temperatures, flow rates, the design approach temperature, the pressure differential at the design flow rates as shown on the Drawings.

3. Submit design, manufacturing and material data in sufficient detail to verify that heat exchangers meet or exceed specification requirements.

4. Submit test reports of heat exchanger pressure tests.

5. Submit manufacturer's operating maintenance and installation (IOM) instructions including recommended insulation type, thickness and jacket material.

6. Submit samples of plates, gaskets and nuts and bolting materials for each heat exchanger size.

B. Operation and Maintenance Data:

1. At Substantial Completion, the contractor shall submit operation and maintenance data that includes Start-up and shutdown instructions, assembly Drawings, and recommended spare parts lists from the manufacturer.

71.6 DELIVERY, STORAGE AND HANDLING

A. Deliver, store, protect and handle products to the Project Site under provisions of Division 01 and Division 20.

B. Protect internals from entry of foreign material by temporary caps on flanged openings.

71.7 EXTRA PARTS

A. Provide set of spare parts as recommended by the manufacturer.

B. Furnish spare parts as shown in the following list as a minimum and to the approval of the engineer:

1. Set of gaskets

2. Guide bar

3. Tie bolts and nuts assembly

71.8 WARRANTY

A. Provide five (5) year manufacturer's unconditional warranty including spare parts and manpower.

PART 72 - PRODUCTS

72.1 GENERAL

A. All materials shall meet or exceed all applicable referenced standards, federal, state and local requirements, and conform to codes and ordinances of authorities having jurisdiction.

B. Number of heat exchangers shall be arranged such as using only two sizes either 500 or 1000 TR.

C. If load is less than 1500 RT, use only multiple of 500 RT size. If load exceeding 1500 RT, use multiple of 1000 RT size. Equal size PHE shall be used in the same project.

D. Number of pumps shall equal number of heat exchangers in addition to one stand-by pump.

E. Furnish and install plate and frame heat exchangers designed with manufacturer's standard fouling allowance and guaranteed to perform to the capacities and pressure drops at the fluid temperatures and flow rates as scheduled. The maximum allowable water pressure drops for the cold and hot sides shall be within 40 - 45 kPa.

F. The plate & frame heat exchanger shall be shipped completely assembled, free standing, full performance and pressure tested at factory, flushed and cleaned and dried, ready for connection at jobsite.

G. Where field erection is required, the manufacturer shall pressure test units at factory, flush and clean and dried, then knock-down and properly crated and marked for erection at jobsite. Manufacturer’s supervision will be required at jobsite and warranties as factory assembled units remain in effect.

H. Units shall be pressure rated for PN 16 cold (distribution system side) and for hot (building side) need to suit the pressure rating of the system in the building side, careful calculation to be performed in the high rise building application with minimum PN16 rating.

I. The plate unit shall be designed to withstand full design pressure in each circuit independently The entire unit shall be hydrostatically tested according to ASME Code, Sect. VIII, Div. 1 for 1.3 x design pressure at maximum working temperature.

J. Numbers of pumps shall match the numbers of serving heat exchangers in addition to one pump stand-by.

72.2 MANUFACTURERS

1. Heat exchanger manufacturer shall have within UAE limits, a fully established service center with Re-conditioning / Re-gasketing facility. The manufacturer shall confirm 24 hours service availability to attend faults at project site by service engineer. The facilities should be approved and certified.
2. The Supplier to confirm availability locally in UAE of all essential spare parts for the plate heat exchanger proposed. The spare parts for the heat exchangers supplied should be maintained for at least 15 years from the date of supply.
3. Supplier to confirm the presence of Factory trained and Qualified Service Engineer to assist in
4. Installation and commissioning at site.
5. The contractor is to submit three manufacturers from the list and the client has the right to select one of them.

72.3 FRAME COMPONENTS

A. Configuration: Each heat exchanger shall be parallel and counter flow, consisting of heat transfer plate with a built in self-aligning system to accurately locate the plates in the frame assembly.

B. Configuration: Manufacturer to provide partial load analysis and Nozzle loads of the proposed units.

C. End-Plate Material: Type SS316, 0.6 mm thick.

D. Plate Material: Plates to be AISI 316 stainless-steel with 2B finishes with minimum thickness of 0.5 mm.

E. The frame shall be a single pass design with all inlet and outlet connections on the fixed cover. The fixed and movable covers shall be of sufficient thickness for design pressure and code requirements and shall have no welded reinforcements or stiffeners.

F. The frame assembly shall be of bolted construction to allow field erection on the site, where required. Welded frame assemblies are not acceptable.

G. The movable cover shall be provided with steel roller bearing for units greater than 1.3 meter height (from bottom of feet) and for units with port sizes 75 mm and larger. This allows the removable cover to be moved without additional rigging or handling equipment.

H. The frame assembly's upper carry and lower guide bars shall be designed to allow for minimum of 25% plate expansion.

I. The portion of the top carrying bar system which comes in contact with the plates shall be stainless steel to prohibit corrosion and facilitate movement of plates. Painted or plated surfaces are not permitted.

J. Provide carbon steel frames, cleaned of mill scale, primed and painted with two (2) coats of baked epoxy enamel.

K. Provide a minimum of two (2) lifting lugs per frame for units with 150 mm ports and larger and designed for lifting assembled flooded unit's flooded weight.

L. The complete assembly to be factory assembled and tested in accordance with ASMEOR PED pressure vessel code requirements and furnished with a certification for the stated design pressure for both circuits.

72.4 PLATES

A. Provide Type 316 stainless steel heat transfer plates with herringbone corrugations designed to provide support to adjacent plates to allow pressurization of each circuit to a full differential with no pressure on the adjacent plate channels without deformation of the heat transfer plates.

B. All plates shall be permanently marked to identify quality and material.

C. All ferrous materials in contact with fluids on the hot and cold sides shall be Type 316 stainless steel.

D. Each heat transfer plate shall have built-in self-aligning system to accurately locate plates in the frame assembly and prevent lateral movement and maintain maximum gasket contact under pressure.

E. Plates shall be reinforced on the upper and lower mounting slots to avoid bending on the plates. Overall plate area should be increased by 10% to account for fouling that will occur as the heat exchanger is being used.

F. Heat transfer plates shall include tapered gasket grooves and shall receive standard IIB finish.

72.5 GASKETS

A. Gaskets shall be one piece molded Nitrile (NRB) rubber compatible with the fluid shown on the plan and schedule and suitable for working temperature up to 120 degrees C. Gaskets shall fit around the heat transfer area and the port holes without the need for glue or adhesive.

B. Gasket shall be permanently marked to identify quality and material.

C. Gasket to have reliving grooves in the double gasketed areas to prevent any cross-contamination between the hot and cold fluids and cause leak to flow outside of unit.

72.6 NOZZLES

A. Provide flanged nozzles (sized as shown on Drawings) on end frames designed for system working pressures as specified. Nozzle velocities shall not exceed 3 m/s at the maximum rate of heat transfer as scheduled on the Drawings.

72.7 BOLTS

A. Compression bolts shall not require the special tools and shall be equipped with lock washers at the movable cover to facilitate opening and closing of a unit from the fixed cover.

B. Compression bolts shall be equipped with captive nuts at the fixed cover and threaded nuts at the removable cover. Welding of the nuts to the closure bolt is prohibited.

C. Bolts shall be provided with rolled threads to reduce galling and double-width hex nuts to distribute the load, plus ball bearing box washers at all critical closing bolts on all units greater than 1.3 meter height.

1. Factory supplied pre-fabricated insulated cover and drip tray. Removable and reusable panel type insulation cover for the PHE enables expedient removal and replacement of insulation to facilitate removal and cleaning of plates. To facilitate assembly and disassembly the insulation pieces shall be held together with stainless steel “suitcase” type latches.

D. Panels shall be 1 mm Alum-stucco 3s ¾ h exterior plating, 60 mm polyurethane foam insulation, 0.05 mm Aluminum foil inside layer and 50 mm Armaflex lining at the bolt holes. Insulated housing to come complete with a drip tray constructed of minimum 0.75 mm stainless steel plate.

1. Heat exchanger to be factory type tested in the presence of the engineer and client to demonstrate full thermal performance at specified conditions. The factory testing shall include for zero tolerance type testing. Performance test shall be witnessed by the client and consultants include for all test charges. Cost shall include full board five stars accommodation, national airline (Emirates) business class for minimum three persons.

72.8 NAME PLATES

A. Each exchanger shall have a stainless-steel nameplate permanently attached to the frame. The nameplate shall be mounted off the surface of the heat exchanger to permit the application of 2-inch-thick insulation.

B. Nameplate brackets shall be fabricated from thermally nonconductive materials to eliminate sweating.

C. The nameplate shall include as a minimum, the following data stamped on the face of the nameplate:

1. Project name.

2. Customer order number.

3. Equipment designation.
4. Year manufactured.
5. Hot and cold side design.
    a. Temperatures.
    b. Working pressures.
    c. Design flow rates.
    d. Pressure differentials at design flow rates.
6. All information required for plate pack compression.
7. Model and serial numbers.

PART 73 - EXECUTION

73.1 INSTALLATION

A. Installation shall meet or exceed all applicable federal, state and local requirements, referenced standards and conform to codes and ordinances of authorities having jurisdiction.

B. All installation shall be in accordance with manufacturer's published IOM and recommendations. Provide a competent, factory trained representative to completely supervise the installation and to perform all on-Site tests.

C. Install to permit disassembly of plate pack with minimum disturbance to piping and equipment. Support heat exchangers on 150 mm housekeeping pads.

D. Install heat exchanger on a reinforced concrete housekeeping pad extending 300 mm beyond the heat exchanger frame in all sides. Area below plates shall be tapered to 75 mm to form a drainage basin, with integral floor drain. Coordinate drain location and provide venting and drain valves for servicing of unit.

E. The plate heat exchanger shall be tested to full test pressure of 1.3 times the design pressure in one circuit with zero pressure in the alternate circuit.

F. Hydrostatic test shall be in accordance with ASME Section VIII, Division 1, and paragraph UG-99. Pipe relief valves to nearest floor drains.

G. Pipe drain and vent valves to nearest floor drain.

H. Provide thermometers, wells and temperature and pressure indicating gauges in supply and return piping at the hot and cold side connections of the exchanger. Also temperature sensors and differential pressure transducer, test points, strainer.

73.2 INSITU FIELD PERFORMANCE TESTING

A. Each non-ARI certified plate heat exchangers shall undergo a field performance test using the mapped ratings, limits and tolerances of ARI Standard 400 to verify performance to specification.

B. Include in the bid price an independent third party field performance test for each plate heat exchanger in accordance with ARI Standard 400 procedures and tolerances

C. Field test instrumentation shall be per ARI Standard 400 and the calibration of all instrumentation shall be traceable to the National Institute of Standards and Technology.

D. Notify the Owner fourteen (14) calendar days in advance to witness the field performance test.

E. A certified test report of all data shall be submitted to the Engineer prior to Substantial Completion. An officer of the manufacturer's company shall sign the field certified test report. Preprinted certification will not be acceptable; certification shall be in the original.]

73.3 CONNECTIONS

A. Piping installation requirements are specified in other Division 15 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Maintain manufacturer's recommended clearances for service and maintenance. Install piping connections to allow service and maintenance of heat exchangers.

C. Install piping with flanged connections at heat exchangers.

D. Install shutoff valves at heat exchanger inlet and outlet connections. E. Install relief valves on heat exchanger heated-fluid connection.

73.4 CLEANING

A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

73.5 COMMISSIONING

A. Verify that heat exchangers are installed and connected according to the Contract Documents.

B. Adjust flows and controls to deliver specified performance.

C. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

73.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain heat exchangers as specified below:

1. Train Owner's maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining heat exchangers.
2. Review data in maintenance manuals. Refer to Division 1 Section "Contract Closeout."
3. Review data in maintenance manuals. Refer to Division 1 Section "Operation and Maintenance Data."
4. Schedule training with Owner, through Engineer, with at least seven days' advance notice.

XXVIII. FAN COIL UNITS

PART 74 - GENERAL

74.1 RELATED DOCUMENTS

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

74.2 SUMMARY

A. This Section includes fan-coil units and accessories.

74.3 DEFINITIONS

A. BAS: Building automation system.

74.4 SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.

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

1. Wiring Diagrams: Power, signal, and control wiring.

C. Coordination Drawings: Floor plans, reflected ceiling plans, and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

1. Ceiling suspension components.
2. Structural members to which fan-coil units will be attached.
3. Method of attaching hangers to building structure.
4. Size and location of initial access modules for acoustical tile.
5. Items penetrating finished ceiling, including the following:
   a. Lighting fixtures.
   b. Air outlets and inlets.
   c. Speakers.
   d. Sprinklers.
   e. Access panels.
6. Perimeter moldings for exposed or partially exposed cabinets.

D. Samples for Initial Selection: For units with factory-applied color finishes.

E. Samples for Verification: For each type of fan-coil unit indicated.

F. Manufacturer Seismic Qualification Certification: Submit certification that fan-coil units, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment." Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2. 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.

G. Field quality-control test reports

H. Operation and Maintenance Data / Manuals including operation in emergency, maintenance schedules and repair part lists for motors, coils, integral controls, and filters.

I. Warranty: Special warranty specified in this Section.

J. Submit clause by clause specification compliance statement to indicate all specified parameters are met.

74.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2004, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

C. ASHRAE/IESNA 90.1-2004 Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2004, Section 6 - "Heating, Ventilating, and Air-Conditioning."

D. Factory test FCU's, before shipping, to verify the fan performance.

1. The tests shall be witnessed by the Engineer at the place where FCU are being tested. Notify Engineer 30 days in advance of testing. Contractor to bear all costs for testing, traveling, boarding/lodging for witnessing the tests.

2. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

74.6 COORDINATION

A. Coordinate layout and installation of fan-coil units and suspension system components with other construction that penetrates or is supported by ceilings, including light fixtures, HVAC equipment, fire-suppression-system components, and partition assemblies.

B. Coordinate size and location of wall sleeves for outdoor-air intake.

74.7 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years from date of Substantial Completion.

74.8 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fan-Coil-Unit Filters: Furnish one spare filter for each filter installed.

2. Fan Belts: Furnish one spare fan belts for each unit installed.

PART 75 - PRODUCTS

75.1 FAN-COIL UNITS

A. Available Manufacturers: Subject to compliance with requirements, provide products in accordance with the approved manufacturers list or approved similar products.

B. Description: Factory-packaged and -tested units rated according to ARI 440, ASHRAE 33, and UL 1995.

C. Coil Section Insulation: 1/2-inch (13-mm) / 1-inch (25-mm) thick, coated glass fiber, foil-covered, closed-cell foam or matte-finish, closed-cell foam complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

1. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

D. Main and Auxiliary Drain Pans: Plastic, Stainless steel or Insulated galvanized steel with plastic liner. Fabricate pans and drain connections to comply with ASHRAE 62.1-2004. Drain pans shall be removable.

E. Chassis:

1. Galvanized steel was exposed to moisture. Floor-mounting units shall have levelling screws.
2. Double skin construction in external car park areas.

F. Cabinet: Steel with baked-enamel finish in manufacturer's standard paint color as selected by Architect

1. Vertical Unit Front Panels: Removable, steel, with integral stamped or steel discharge grille and channel-formed edges, cam fasteners, and insulation on back of panel.
2. Horizontal Unit Bottom Panels: Fastened to unit with cam fasteners and hinge and attached with safety chain; with integral stamped or cast-aluminum discharge grilles.
3. Steel recessing flanges for recessing fan-coil units into ceiling or wall.

G. Filters: Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2 and equipment schedule.

H. Hydronic Coils: Four rows copper tube, with mechanically bonded aluminium fins spaced no closer than 0.1 inch (2.5 mm), rated for a minimum working pressure of 200 psig (1378 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.

I. Fan and Motor Board: Removable.

1. Fan: Forward curved, double width, centrifugal; directly connected to motor. Thermoplastic or painted-steel wheels, and aluminium, painted-steel, or galvanized-steel fan scrolls.
2. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."
3. Wiring Termination: Connect motor to chassis wiring with plug connection.

J. Factory, Hydronic Piping Package: ASTM B 88, Type L (ASTM B 88M, Type B) / ASTM B 88, Type M (ASTM B 88M Type C) copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.

1. Two or Three-way, modulating control valve for chilled-water coil.
2. Two or Three-way, modulating control valve for heating coil.
3. Hose Kits: Minimum 400-psig (2758-kPa) working pressure, and operating temperatures from 33 to 211 deg F (0.5 to 99 deg C). Tag hose kits to equipment designations.
   a. Length: 24 inches (600 mm) / 36 inches (900 mm).
   b. Minimum Diameter: Equal to fan-coil-unit connection size.
4. Two-Piece Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig (4140-kPa) minimum CWP rating and blowout-proof stem.
5. Calibrated-Orifice Balancing Valves: Bronze body, ball type; 125-psig (860-kPa) working pressure, 250-deg F (121-deg C) maximum operating temperature; with calibrated orifice or venturi, connections for portable differential pressure meter with integral seals, threaded ends, and equipped with a memory stop to retain set position.
6. Automatic Flow-Control Valve: Brass or ferrous-metal body; 300-psig (2070-kPa) working pressure at 250 deg F (121 deg C), with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of 2 to 80 psig (13.8 to 552 kPa).
7. Y-Pattern Hydronic Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig (860-kPa) working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 (DN 15) hose-end, full-port, ball-type blowdown valve in drain connection.
8. Wrought-Copper Unions: ASME B16.22.

K. Control devices and operational sequences are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."

L. Basic Unit Controls:

1. Control voltage transformer.
2. Wall-mounting thermostat with the following features:
   a. Heat-cool-off switch.
   b. Fan on-auto switch.
   c. Fan-speed switch.
   d. Automatic changeover.
   e. Adjustable dead band.
   f. Degree Celsius indication.
3. Wall-mounting temperature sensor.
4. Unoccupied-period-override push button.

M. Electrical Connection: Factory wire motors and controls for a single electrical connection.

PART 76 - EXECUTION

76.1 EXAMINATION

A. Examine areas to receive fan-coil units for compliance with requirements for installation tolerances and other conditions affecting performance.

B. Examine roughing-in for piping and electrical connections to verify actual locations before fan-coil-unit installation.

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

76.2 INSTALLATION

A. Install fan-coil units level and plumb.

B. Install fan-coil units to comply with NFPA 90A.

C. Suspend fan-coil units from structure with elastomeric hangers. Vibration isolators are specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

D. Verify locations of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation.

E. Install new filters in each fan-coil unit within two weeks after Substantial Completion.

76.3 CONNECTIONS

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

1. Install piping adjacent to machine to allow service and maintenance.
2. Connect piping to fan-coil-unit factory hydronic piping package. Install piping package if shipped loose.
3. Connect condensate drain to indirect waste.
    a. Install condensate trap of adequate depth to seal against the pressure of fan. Install cleanouts in piping at changes of direction.

B. Connect supply and return ducts to fan-coil units with flexible duct connectors specified in Division 23 Section "Air Duct Accessories." Comply with safety requirements in UL 1995 for duct connections.

76.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
2. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

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

76.5 ADJUSTING

A. Adjust initial temperature set points.

B. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other than normal occupancy hours for this purpose.

76.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain fan-coil units.

XXIX. DIRECT DIGITAL CONTROL SYSTEM FOR HVAC

PART 77 - PART 1: GENERAL

(a) 1.1 WORK INCLUDED

(b) A. Furnish a totally native BACnet-based system, including a Microsoft Vista compatible operator’s workstation. The operator’s workstation, all building controllers, application controllers, and all input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135–2008, BACnet. In other words, all workstations and controllers, including unitary controllers, shall be native BACnet devices. No gateways shall be used for communication to controllers installed under this section. Gateways may be used for communication to existing systems or to systems installed under other sections.

(c) B. Provide all necessary BACnet-compliant hardware and software to meet the system’s functional specifications. Provide Protocol Implementation Conformance Statement (PICS) for Windows-based control software and every controller in system, including unitary controllers.

(d) C. Prepare individual hardware layouts, interconnection drawings, and software configuration from project design data.

(e) D. Implement the detailed design for all analog and binary objects, system databases, graphic displays, logs, and management reports based on control descriptions, logic drawings, configuration data, and bid documents.

(f) E. Design, provide, and install all equipment cabinets, panels, data communication network cables needed, and all associated hardware.

(g) F. Provide and install all interconnecting cables between supplied cabinets, application controllers, and input/output devices.

(h) G. Provide and install all interconnecting cables between all operator’s terminals and peripheral devices (such as printers, etc.) supplied under this section.

(i) H. Provide complete manufacturer’s specifications for all items that are supplied. Include vendor name of every item supplied.

(j) I. Provide supervisory specialists and technicians at the job site to assist in all phases of system installation, startup, and commissioning.

(k) J. Provide a comprehensive operator and technician training program as described herein.

(l) K. Provide as-built documentation, operator’s terminal software, diagrams, and all other associated project operational documentation (such as technical manuals) on approved media, the sum total of which accurately represents the final system.

(m) L. Provide new sensors, dampers, valves, and install only new electronic actuators. No used components shall be used as any part or piece of installed system.

(n) 1.2 SYSTEM DESCRIPTION

(o) A. A distributed logic control system complete with all software and hardware functions shall be provided and installed. System shall be completely based on ANSI/ASHRAE Standard 135-2008, BACnet and achieved listing under the BACnet Testing Laboratories BACnet - Advanced Workstation Software (B-AWS). This system is to control all mechanical equipment, including all unitary equipment such as VAV boxes, heat pumps, fan-coils, AC units, etc., and all air handlers, boilers, chillers, and any other listed equipment using native BACnet-compliant components. Non-BACnet-compliant or proprietary equipment or systems (including gateways) shall not be acceptable and are specifically prohibited.

(p) **Note to Specifier:** Add irrigation, lighting control, any other monitoring in this paragraph, to make sure it is included in project bids and delivered by contractors.

(q) B. Operator’s workstation software shall use Microsoft Windows XP Professional, Microsoft Vista “Ultimate Enterprise” editions, or Microsoft Windows 7 as the computer operating system. The Energy Management and Control System (EMCS) application program shall be written to communicate specifically utilizing BACnet protocols. Software functions delivered on this project shall include password protection, scheduling (including optimum start), alarming, logging of historical data, full graphics including animation, after-hours billing program, demand limiting, and a full suite of field engineering tools including graphical programming and applications. Systems using operating systems other than that described above are strictly prohibited. All software required to program application specific controllers and all field level devices and controllers will be left with the owner. All software passwords required to program and make future changes to the system will also become the property of the owner. All software required to make any program changes anywhere in the system, along with scheduling and trending applications, will be left with the owner. All software passwords required to program and make future changes to schedules, trends and related program changes will also become the property of the owner. All software required for all field engineering tools including graphical programming and applications will be left with the owner. All software passwords required to program and make future changes to field engineering tools, including graphical programming and applications will be left with the owner.

(r) C. Building controllers shall include complete energy management software, including scheduling building control strategies with optimum start and logging routines. All energy management software and firmware shall be resident in field hardware and shall not be dependent on the operator’s terminal. Operator’s terminal software is to be used for access to field-based energy management functions only. Provide zone-by-zone direct digital logic control of space temperature, scheduling, runtime accumulation, equipment alarm reporting, and override timers for after-hours usage.

(s) D. Room sensors shall be provided with digital readout that allow the user to view room temperature, view outside air temperature, adjust the room setpoint within preset limits and set desired override time. User shall also be able to start and stop unit from the digital sensor. Include all necessary wiring and firmware such that room sensor includes field service mode. Field service mode shall allow a technician to balance VAV zones and access any parameter in zone controller directly from the room sensor. Field service mode shall have the ability to be locked out.

(t) **Note to Specifier:** If digital readout not desired, replace with the following: Room sensors shall be architecturally pleasing, sense temperature, allow tenant to override system and adjust temperature setpoint, and include a jack that allows the service technician to adjust any zone parameter. Include all wiring for sensor and field service tool.

(u) E. All application controllers for every terminal unit (VAV, HP, UV, etc.) air handler, all central plant equipment, and any other piece of controlled equipment shall be fully programmable. Application controllers shall be mounted next to controlled equipment and communicate with building controller through BACnet LAN.

(v) 1.3 APPROVED MANUFACTURERS

(w) A. The base bid shall be the BACtalk system from Alerton. Other manufacturers may bid based upon meeting all requirements of the specification and receiving approval from the engineer 30 days prior to bid. A paragraph-by-paragraph comparison of based bid specified system versus alternative system—along with three references of similar projects (include project name, contact, phone number, location, consultant, value of contract, and a brief description of the control system and how it operates—shall be submitted 45 days prior to bid for review process. If approved, other manufacturers’ bids shall be shown as an add or deduct on the bid form.

Approved Control Manufacturers

1. Alerton
2. XXXXXX
3. XXXXXX

(x) 1.4 QUALITY ASSURANCE

(y) A. The Building Automation System (BAS) system shall be designed, installed, commissioned, and serviced by manufacturer authorized and trained personnel. System provider shall have an in-place support facility within 2 hours response time of the site with technical staff, spare parts inventory, and necessary test and diagnostic equipment.

The contractor shall provide full-time, on-site, experienced project manager for this work, responsible for direct supervision of the design, installation, start-up and commissioning of the BAS system.

The Bidder shall be regularly engaged in the design, installation and maintenance of BAS systems and shall have demonstrated technical expertise and experience in the design, installation and maintenance of BAS systems similar in size and complexity to this project. Bidders shall provide a list of at least 10 projects, similar in size and scope to this project completed within the past 3 years.

(z) B. Materials and equipment shall be manufacturer's latest standard design that complies with the specification requirements.

(aa) C. All BAS peer-to-peer network controllers, central system controllers and local user displays shall be UL Listed under Standard UL 916, category PAZX.

(bb) D. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference and be so labeled.

(cc) E. Control system shall be engineered, programmed and supported completely by representative's local office that must be within **100 miles** of project site.

(dd) **Note to Specifier:** Update based upon project.

(ee) 1.5 REFERENCE STANDARDS

(ff) A. The latest edition of the following standards and codes in effect and amended as of supplier's proposal date, and any applicable subsections thereof, shall govern design and selection of equipment and material supplied:

1. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
2. ANSI/ASHRAE Standard 135-2008, BACnet.
3. Uniform Building Code (UBC), including local amendments.
4. UL 916 Underwriters Laboratories Standard for Energy Management Equipment. Canada and the US.
5. National Electrical Code (NEC).
6. FCC Part 15, Subpart J, Class A.
7. EMC Directive 89/336/EEC (European CE Mark).
8. UL-864 UUKL listing for Smoke Controls for any equipment used in smoke control sequences.

(gg) B. City, county, state, and federal regulations and codes in effect as of contract date.

(hh) C. Except as otherwise indicated, the system supplier shall secure and pay for all permits, inspections, and certifications required for his work, and arrange for necessary approvals by the governing authorities.

(ii) 1.6 SUBMITTALS

(jj) A. Drawings

1. The system supplier shall submit engineered drawings, control sequence, and bill of materials for approval.
2. Drawings shall be submitted in the following standard sizes: 11" x 17" (ANSI B).

3. Eight complete sets (copies) of submittal drawings shall be provided.

4. Drawings shall be available on CD-ROM.

(kk) B. System Documentation

Include the following in submittal package:

(ll) 1. System configuration diagrams in simplified block format.

(mm) 2. All input/output object listings and an alarm point summary listing.

(nn) 3. Electrical drawings that show all system internal and external connection points, terminal block layouts, and terminal identification.

(oo) 4. Complete bill of materials, valve schedule and damper schedule.

(pp) 5. Manufacturer's instructions and drawings for installation, maintenance, and operation of all purchased items.

(qq) 6. Overall system operation and maintenance instructions—including preventive maintenance and troubleshooting instructions.

(rr) 7. For all system elements—operator’s workstation(s), building controller(s), application controllers, routers, and repeaters—provide BACnet Protocol Implementation Conformance Statements (PICS) as per ANSI/ASHRAE Standard 135-2001.

(ss) 8. Provide complete description and documentation of any proprietary (non-BACnet) services and/or objects used in the system.

(tt) 9. A list of all functions available and a sample of function block programming that shall be part of delivered system.

(uu) C. Project Management

(vv) 1. The vendor shall provide a detailed project design and installation schedule with time markings and details for hardware items and software development phases. Schedule shall show all the target dates for transmission of project information and documents, and shall indicate timing and dates for system installation, debugging, and commissioning.

(ww) 1.7 WARRANTY

(xx) A. Warranty shall cover all costs for parts, labor, associated travel, and expenses for a period of one year from completion of system acceptance.

(yy) B. Hardware and software personnel supporting this warranty agreement shall provide on-site or off-site service in a timely manner after failure notification to the vendor. The maximum acceptable response time to provide this service at the site shall be 24 hours, Monday through Friday and 48 hours on Saturday and Sunday.

(zz) C. This warranty shall apply equally to both hardware and software.

(aaa) 1.8 RELATED WORK IN OTHER SECTIONS

(bbb) **Note to Specifier:** Use this section to spell out those other areas of the specification that the control system contractor needs to review. This should include all contractual items and all areas that will interface with the control systems such as lighting, irrigation, chillers, fire alarm, etc.

(ccc) A. Refer to Division 0 and Division 1 for related contractual requirements.

(ddd) B. Refer to Section 23 00 00 for General Mechanical Provisions.

(eee) C. Refer to Section 26 00 00 for General Electrical Provisions.

(fff)

PART 78 - PART 2: PRODUCTS

(ggg) 2.1 OPERATOR'S WORKSTATION

(hhh) A. General structure of workstation interaction shall be a standard client/server relationship. Server shall be used to archive data and store system database. Clients shall access server for all archived data. Each client shall include flexibility to access graphics from server or local drive. Server shall support a minimum of 50 simultaneous clients.

(iii) B. BACnet Conformance

1. Operator workstation shall be approved by the BTL as meeting the BACnet Advanced Work Station (AWS) requirements.

(jjj) 2. Please refer to Section 22.2, BACnet Functional Groups, in the BACnet standard, for a complete list of the services that must be directly supported to provide each of the functional groups listed above. All proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(kkk) 3. Standard BACnet object types accessed by the AWS shall include as a minimum: Analog Value, Analog Input, Analog Output, Binary Value, Binary Input, Binary Output, Calendar, Device, Event Enrollment, File, Notification Class, Program, and Schedule object types. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(lll) 4. The AWS shall comply with Annex J of the BACnet specification for IP connections. Must support remote connection to server using a thick client application. This device shall use Ethernet to connect to the IP internetwork, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the LAN. Must support interoperability on wide area networks (WANs) and campus area networks (CANs). AWS shall support Foreign Device Registration to allow temporary workstation connection to IP network.

(mmm) C. Data Displays

(nnn) 1. Data displays shall render all data associated with project as called out on drawings and/or object type list supplied. Graphic files shall be created using digital, full color photographs of system installation, AutoCAD or Visio drawing files of field installation drawings, and wiring diagrams from as-built drawings.

(ooo) 2. Data displays shall render all data using iconic graphic representations of all mechanical equipment. System shall be capable of displaying graphic file, text, and dynamic object data together on each display and shall include animation. Information shall be labeled with descriptors and shall be shown with the appropriate engineering units. All information on any display shall be dynamically updated without any action by the user.

(ppp) 3. Data display frame shall allow user to change all field-resident AWS functions associated with the project, such as setpoints, weekly schedules, exception schedules, etc., from any screen, no matter if that screen shows all text or a complete graphic display. This shall be done without any reference to object addresses or other numeric/mnemonic indications.

(qqq) 4. Analog objects shall be displayed with operator modifiable units. Analog input objects may also be displayed as individual graphic items on the display screen as an overlay to the system graphic.

(rrr) 5. All displays and programming shall be generated and customized by the local use energy management and control system (EMCS) supplier and installer. Systems requiring factory development of graphics or programming of DDC logic are specifically prohibited.

(sss) 6. AWS shall be supplied with a library of standard graphics, which may be used unaltered or modified by the operator. AWS shall include a library of equipment graphic components to assemble custom graphics. Systems that do not allow customization or creation of new graphic objects by the operator (or with third-party software) shall not be allowed.

(ttt) 7. Data display frame shall include customizable and persistent tree navigation for building, equipment and system diagnostic centric display organization.

(uuu) 8. Each display may be protected from viewing unless operator credentials have the appropriate access level. An access level may be assigned to each display and system object. The menu label shall not appear on the graphic if the operator does not have the appropriate security level.

(vvv) 9. Data displays shall have the ability to link to content outside of the EMCS system. Such content shall include, but is not limited to launching external files in their native applications (for example, a Microsoft Word document) and launching a web browser resolving to a specified web address.

(www) 10. The AWS shall have the ability to support 20 concurrent web clients.

(xxx) 11. Data displays shall support:

(i) a. Graphic items with custom geometry that offer both color gradient shading and variable opacity in scale to system variables and range setpoints.

(ii) b. Clear and custom geometry navigation buttons to provide intuitive navigation.

(iii) c. Graphic files in JPG, PNG, and GIF file types.

(iv) d. Viewing of 1,024 system data points in a single screen.

(yyy) D. Password Protection

1. Provide security system that prevents unauthorized use unless operator is logged on. Access shall be limited to operator’s assigned functions when user is logged on. This includes displays as outlined above.
2. AWS shall provide security for a minimum of 200 users. Each user shall have an individual User ID, User Name, and Password. Entries are alphanumeric characters only and are case sensitive (except for User ID). User ID shall be 0–8 characters, User Name shall be 0–29 characters, and Password shall be 4–8 characters long.
3. Each user shall be allowed individual assignment of only those control functions, menu items, and user-specific system start display, as well as restricted access to discrete BACnet devices to which that user requires access.
4. All passwords, user names, and access assignments shall be adjustable online at the operator’s terminal.
5. Users shall also have a set access level, which defines access to displays and individual objects the user may control. System shall include 10 separate and distinct access levels for assignment to users.
6. The system shall include an Auto Logout feature that shall automatically logout user when there has been no keyboard or mouse activity for a set period of time. Time period shall be adjustable by system administrator. Auto Logout may be enabled and disabled by system administrator. Operator terminal shall display message on screen that user is logged out after Auto Logout occurs.
7. The system shall permit the assignment of an effective date range, as well as an effective time of day, that the User IDs are permitted to authenticate.

(zzz) E. Operator Activity Log

(aaaa) 1. An Operator Activity Log that tracks all operator changes and activities shall be included with AWS. System shall track what is changed in the system, who performed this change, date and time of system activity, and value of the change before and after operator activity. Operator shall be able to display all activity, sort the changes by user and also by operation. Operator shall be able to print the Operator Activity Log display.

(bbbb) 2. Log shall be gathered and archived to a hard drive on AWS as needed. Operator shall be able to export data for display and sorting in a spreadsheet.

(cccc) F. Scheduling

1. AWS and web client shall show all information in easy-to-read daily format including calendar of this month and next. All schedules shall show actual ON/OFF times for day based on scheduling priority. Priority for scheduling shall be events, holidays and daily, with events being the highest.

2. Holiday and special event schedules shall display data in calendar format. Operator shall be able to schedule holidays and special events directly from these calendars.

3. Operator shall be able to change all information for a given weekly or exception schedule if logged on with the appropriate access privileges.

4. AWS shall include a Schedule Wizard for set up of schedules. Wizard shall walk user through all steps necessary for schedule generation. Wizard shall have its own pull-down selection for startup or may be started by right-clicking on value displayed on graphic and then selecting Schedule.

5. Scheduling shall include optimum start based on outside air temperature, current heating/cooling setpoints, indoor temperature and history of previous starts. Each and every individual zone shall have optimum start time independently calculated based on all parameters listed. User shall input schedules to set time that occupied setpoint is to be attained. Optimum start feature shall calculate the startup time needed to match zone temperature to setpoint. User shall be able to set a limit for the maximum startup time allowed.

6. Schedule list shall show all schedules currently defined. This list shall include all standard, holiday and event schedules. In addition, user shall be able to select a list that shows all scheduled points and zones.

7. Display of all three schedules must show all ON times for standard, holiday and event schedules in different colors on a given day. In addition, OFF times for each must also be shown in additional colors. User shall be able to select from standard calendar what days are to be scheduled and same display shall show all points and zones affected. User shall be able to set time for one day and select all days of the week that shall be affected as a recurrence of that same schedule for that given day.

8. Any displayed data that is changeable by the operator may be selected using the right mouse button and the schedule shall then be selectable on the screen. Selection of the schedule using this method shall allow the viewing of the assigned schedule allow the point to be scheduled.

9. Schedule editor shall support drag-n-drop events and holidays onto the schedule calendar.

10. Schedule editor shall support drag-n-drop events default to a two-hour period, which can then be adjusted by the user.

11. Schedule editor shall support drag-n-drop holidays default for OFF all day and can be edited for multiple-day holidays.

12. Schedule editor shall support the view of affected zones when adding or editing timed events of a schedule.

(dddd) G. Alarm Indication and Handling.

1. AWS shall provide visual, printed, and email means of alarm indication. Printout of alarms shall be sent to the assigned terminal and port. Alarm notification can be filtered based on the User ID's authorization level.

2. Web client shall display a persistent alarm state for the system regardless of the data view including points in alarm but not acknowledged, and points that have gone into alarm and returned to normal without being acknowledged.

3. Alarm History shall provide log of alarm messages. Alarm log shall be archived to the hard disk of the AWS. Each entry shall include a description of the event-initiating object generating the alarm. Description shall be an alarm message of at least 256 characters in length. Entry shall include time and date of alarm occurrence, time and date of object state return to normal, time and date of alarm acknowledgment, and identification of operator acknowledging alarm.

4. Alarm messages shall be in user-definable text (English or other specified language) and shall be delivered either to the operator's terminal, client or through remote communication using email (Authenticated SMTP supported).

5. AWS shall include an Alarm Wizard for set up of alarms. Wizard shall walk user through all steps necessary for alarm generation. Wizard shall have its own pull-down selection for startup or may be started by right-clicking on value displayed on graphic and then selecting alarm setup.

6. AWS shall support color-coded indication of current alarms as follows:

(i) a. Red indicator shows number of active alarms that have not been acknowledged.

(ii) b. Yellow indicator shows number of alarms that are still active but have been acknowledged.

(iii) c. Blue indicator shows number of alarms that have returned to normal but have not been acknowledged.

(iv) d. Color-coded indicators, when selected by the user, navigate to a pre-filtered view of alarm history.

(v) e. Alarm history can be filtered by color-coded indicator states.

(eeee) 7. Alarm annunciation includes navigation link to a user-selected display or URL.

(ffff)8. User can silence audible annunciation for the current session.

(gggg) 9. User can disable auto-refresh of alarm annunciation for current session.

(hhhh) 10. Any displayed data that is changeable by the operator may be selected using the right mouse button and the alarm shall then be selectable on the screen. Selection of the alarm using this method shall allow the viewing of the alarm history or allow the creation of a new alarm.

(iiii) H. Trendlog Information

1. AWS shall periodically gather historically recorded data stored in the building controllers and store the information in the system database. Stored records shall be appended with new sample data, allowing records to be accumulated. Systems that write over stored records shall not be allowed unless limited file size is specified. System database shall be capable of storing up to 50 million records before needing to archive data. Samples may be viewed at the web client. Operator shall be able to view all trended records, both stored and archived. All trendlog records shall be displayed in standard engineering units.

2. AWS shall be capable of trending on an interval determined by a polling rate, or

change-of-value.

3. AWS shall be able to change trendlog setup information. This includes the information to be logged as well as the interval at which it is to be logged. All operations shall be password protected. Viewing may be accessed directly from any and all graphics on which a trended object is displayed.

4. AWS shall include a Trendlog Wizard for setup of logs. Wizard shall walk user through all necessary steps. Wizard shall have its own pull-down selection for startup, or may be started by right-clicking on value displayed on graphic, and then selecting Trendlogs from the displayed menu.

5. AWS shall be capable of using Microsoft SQL as the system database.

6. Any displayed data that is changeable by the operator may be selected using the right mouse button and the trendlog shall then be selectable on the screen. Selection of the trendlog using this method shall allow the viewing of the trendlog view.

7. Trendlog viewer shall provide:

(i) a. Software that is capable of graphing the trend-logged object data shall be included.

(ii) b. Access and ability to create, edit and view are restricted to users by user account credentials

(iii) c. Specific and repeatable URL defines the trendlog(s) that comprise the view.

(iv) d. Call out of trendlog value at intersection of trend line and mouse-over vertical axis.

(v) e. Trendlog and companion logs can be configured to display on one of two independent vertical scales.

(vi) f. Click zoom for control of data set viewed along either graph axis.

(vii) g. User-specifiable start and end dates as well as a fast scroll features that supports click zoom of macro scale view of the data for quickly finding data set based on visual signature.

(viii) h. User export of the viewed data set to MS Excel.

(ix) i. Web browser-based help.

(x) j. Optional min/max ranges (Upper Control Limits, Lower Control Limits) for each value.

(jjjj) I. Energy Log Information

1. AWS shall be capable of periodically gathering energy log data stored in the field equipment and archive the information. Archive files shall be appended with new data, allowing data to be accumulated. Systems that write over archived data shall not be allowed unless limited file size is specified. Display all energy log information in standard engineering units.

2. All data shall be stored in database file format for direct use by third-party programs. Operation of system shall stay completely online during all graphing operations.

3. AWS operator shall be able to change the energy log setup information as well. This includes the meters to be logged, meter pulse value, and the type of energy units to be logged. All meters monitored by the system may be logged. System shall support using flow and temperature sensors for BTU monitoring.

4. AWS shall display archived data in tabular format form for both consumption and peak values. Data shall be shown in hourly, daily, weekly, monthly and yearly formats. In

each format, the user shall be able to select a specific period of data to view.

(kkkk) J. Demand Limiting

1. AWS shall include demand limiting program that includes two types of load shedding. One type of load shedding shall shed/restore equipment in binary fashion based on energy usage when compared to shed and restore settings. The other type of shedding shall adjust operator-selected control setpoints in an analog fashion based on energy usage when compared to shed and restore settings. Shedding may be implemented independently on each and every zone or piece of equipment connected to system.

2. Binary shedding shall include minimum of five (5) priority levels of equipment shedding. All loads in a given priority level shall be shed before any loads in a higher priority level are shed. Load shedding within a given priority level shall include two methods. In one, the loads shall be shed/restored in a “first off-first on” mode, and in the other the loads are just shed/restored in a “first off-last on” (linear) fashion.

3. Analog shed program shall generate a ramp that is independently used by each individual zone or individual control algorithm to raise the appropriate cooling setting and lower appropriate heating setting to reduce energy usage.

4. AWS shall be able to display the status of each and every load shed program. Status of each load assigned to an individual shed program shall be displayed along with English description of each load.

(llll) K. Tenant Activity

1. AWS shall include program that monitors after-hours overrides by tenants, logs that data, and generates a bill based on usage and rate charged for each tenant space. Tenant Activity program shall be able to assign multiple zones, from a list of every zone connected to system, to a particular tenant. Every zone is monitored for after-hours override usage and that data logged in AWS. Operator may then generate a bill based on the usage for each tenant and the rate charged for any overtime use.

2. Configuration shall include entry of the following information for use in logging and billing:

(i) a. Tenant’s contact name and address

(ii) b. One or multiple tenant zones that make up a total tenant space, including a separate billing rate for each separate zone

(iii) c. Minimum and maximum values an event duration and event limit

(iv) d. Property management information

(v) e. Overall billing rate

(vi) f. Seasonal adjustments or surcharge to billing rate

(vii) g. Billing notification type including, but not limited to printer, file and email

(viii) h. Billing form template

3. Logging shall include recording the following information for each and every tenant event:

(ix) a. Zone description

(x) b. Time the event begins

(xi) c. Total override time

(xii) d. Limits shall be applied to override time

4. A tenant bill shall be generated for a specific period using all the entered configuration data and the logged data. User with appropriate security level shall be able to view and override billing information. User shall be able to select a billing period to view and be able to delete events from billing and edit a selected tenant activity event's override time.

(mmmm) L. Reports

1. AWS shall be capable of periodically producing reports of trendlogs, alarm history, tenant activities, device summary, energy logs, and override points. The frequency, content, and delivery are to be user adjustable.

2. All reports shall be capable of being delivered in multiple formats including text- and comma-separated value (CSV) files. The files can be printed, emailed, or saved to a folder, either on the server hard drive or on any network drive location.

(nnnn) M. Configuration/Setup

1. Provide means for operator to display and change system configuration. This shall include, but not be limited to system time, day of the week, date of daylight savings set forward/set back, printer termination, port addresses, modem port and speed, etc. Items shall be modified using understandable terminology with simple mouse/cursor key movements.

(oooo) N. Field Engineering Tools

1. AWS shall include field engineering tools for programming all controllers supplied. All controllers shall be programmed using graphical tools that allow the user to connect function blocks on screen that provide sequencing of all control logic. Function blocks shall be represented by graphical displays that are easily identified and distinct from other types of blocks. Graphical programming that uses simple rectangles and squares is not acceptable.

2. User shall be able to select a graphical function block from menu and place on screen. Provide zoom in and zoom out capabilities. Function blocks shall be downloaded to controller without any reentry of data.

3. Programming tools shall include a real-time operation mode. Function blocks shall display real-time data and be animated to show status of data inputs and outputs when in real-time operation. Animation shall show change of status on logic devices and countdown of timer devices in graphical format.

4. Field engineering tools shall also include a database manager of applications that include logic files for controllers and associated graphics. Operator shall be able to select unit type, input/output configuration and other items that define unit to be controlled. Supply minimum of 250 applications as part of workstation software.

5. Field engineering tool shall include Device Manager for detection of devices connected anywhere on the BACnet network by scanning the entire network. This function shall display device instance, network identification, model number, and description of connected devices. It shall record and display software file loaded into each controller. A copy of each file shall be stored on the computer's hard drive. If needed, this file shall be downloaded to the appropriate controller using the mouse.

6. AWS shall automatically notify the user when a device that is not in the database is added to the network.

7. AWS shall include backup/restore function that will back up entire system to selected medium and then restore system from that medium. The system shall be capable of creating a backup for the purpose of instantiating a new client PC.

8. The system shall provide a means to scan, detect, interrogate, and edit third-party BACnet devices and BACnet objects within those devices.

(pppp) O. Workstation Hardware

1. Provide operator's workstation(s) at location(s) noted on the plans.

2. AWS server

   a. 64-bit OS

   b. Windows 7, Windows 8, Windows 8.1, Windows Server 2012

   c. 2 GHz (or better), one or more dual-core or quad-core processors

   d. 8 GB RAM or higher

   e. 3 GB of hard drive space required for base installation without application data

   f. Network interface card (10/100/1000 Mbps)

(qqqq) **Note to Specifier:** Review regularly, add processing power as required for specific job.

(rrrr) P. Software

1. At the conclusion of the project, contractor shall leave with owner a CD-ROM that includes the complete software operation system and project graphics, setpoints, system parameters, etc. This backup shall allow the owner to completely restore the system in the case of a computer malfunction.

(ssss) Q. Web Client

(tttt)1. EMCS supplier shall provide an HTML5-based browser access to the AWS as part of standard installation. User must be able to access all displays of real-time data that are part of the AWS using a standard web browser. Web browser shall tie into the network through owner-supplied Ethernet network connection. The AWS must be able to support 20 concurrent web client users.

(uuuu) 2. Browser shall be standard version of Microsoft Internet Explorer v10.0 or later, Firefox v19.0 or later and Chrome v24.0 or later. No special vendor-supplied software shall be needed on computers running browser. Data shall be displayed in real-time and update automatically without user interaction.

(vvvv) 3. Web pages shall be automatically generated using HTML5 from the data display files that reside on the AWS. Any system that requires use of an HTML editor for generation of web pages shall not be considered.

(wwww) 4. Access through web client or thick client shall utilize the same hierarchical security scheme as the AWS. User shall be asked to log on once the client makes connection to the AWS. Once the user logs on, any and all changes that are made shall be tracked by the AWS. The user shall be able to change only those items he or she has authority to change. A user activity report shall show any and all activity of the users who have logged on to the system, regardless of whether those changes were made using a web client, thick client or through the AWS.

(xxxx) 2.2 WEB INTERFACE

(yyyy) **Note to Specifier:** Requires addition of Alerton Building Suite 3 or BCM-WEB as project size dictates.

(zzzz) A. General

BAS supplier shall provide Web-based access to the system as part of standard installation. User must be able to access all displays of real-time data that are part of the BAS using a standard Web browser. Web browser shall tie into the network through owner-supplied Ethernet network connection. Web page host shall be a separate device that resides on the BAS BACnet network, but is not the BAS server for the control system. BAS server must be a separate computer from the Web page host device to ensure data and system integrity. The Web page software shall not require a per-user licensing fee or annual fees. The Web page host must be able to support on average 50 simultaneous users with the ability to expand the system to accommodate an unlimited number of users.

(aaaaa) B. Browser Technology

Browser shall be standard version of Microsoft Internet Explorer v6.0 or later, Firefox v2.0 or later and Safari v2.0 or later (on Mac OS X). PDA browser connection shall be Pocket PC 2003, Windows Mobile 5.0, or Blackberry. No special vendor-supplied software shall be needed on computers running browser. All displays shall be viewable and the Web page host shall directly access real-time data from the BAS BACnet network. Data shall be displayed in real-time and update automatically without user interaction. User shall be able to change data on displays if logged in with the appropriate user name and password.

(bbbbb) C. Communications

1. Web page host shall include two Ethernet network connections. One network connection shall be dedicated to BAS BACnet network and shall be used to gather real-time data from all the BACnet devices that form the BAS. This network shall communicate using BACnet, allowing the Web page host to gather data directly from units on the local LAN or from other projects connected over a WAN. This network shall also provide the connection to the BAS server for Web page generation.

2. The second Ethernet connection shall provide the physical connection to the Internet or an IP-based WAN. It shall be the port that is used for the browser to receive Web pages and data from the Web page host. The Web page host shall act as a physical barrier between the BAS network and the WAN or Internet connection that allows the browser to receive Web pages and data. The two separate network connections provide for a physical barrier to prevent raw BACnet traffic being exposed on the IP network.

3. The Web page host shall provide for complete isolation of the IP and BACnet networks by not routing networking packets between the two networks.

4. BAS BACnet Ethernet network shall be provided and installed by the BAS supplier. Owner shall provide and incur any monthly charges of WAN/Internet connection.

(ccccc) D. Display of Data

1. Web page graphics shown on browser shall be replicas of the BAS displays. User shall need no additional training to understand information presented on Web pages when compared to what is shown on BAS displays. Web page displays shall include animation just as BAS displays. Fans shall turn, pilot lights shall blink, coils shall change colors, and so on.

2. Real-time data shall be shown on all browser Web pages. This data must be directly gathered using the BACnet network and automatically updated on browser Web page displays without any user action. Data on the browser shall automatically refresh as changes are detected without re-drawing the complete display.

3. It shall be possible for user from browser Web page to change data if the user is logged on with the appropriate password. Clicking on a button or typing in a new value shall change digital data. Using pull-down menus or typing in a new value shall change analog data.

4. Data displays shall be navigated using pushbuttons on the displays that are simply clicked on with the mouse to select a new display. Alternatively, the standard back and forward buttons of the browser can be used for display navigation.

(ddddd) E. Time Schedule Adjustment

1. Web access shall allow user to view and edit all schedules in the system. This includes standard, holiday and event schedules as described in BAS specification. Display of schedules shall show interaction of all schedules on a single display so user sees an overview of how all work together. User shall be able to edit schedules from this display.

2. Display of all three schedules must show all ON times for standard, holiday and event schedules in different colors on a given day. In addition, OFF times for each must also be shown in additional colors. User shall be able to select from standard calendar

what days are to be scheduled and same display shall show all points and zones affected. User shall be able to set time for one day and select all days of the week that shall be affected as a recurrence of that same schedule for that given day.

3. Schedule list shall show all schedules currently defined. This list shall include all standard, holiday and event schedules. In addition, user shall be able to select a list that shows all scheduled points and zones.

(eeeee) F. Logging of Information

User shall use standard browser technology to view all trendlogs in system. User shall be able to view logged data in tabular form or graphical format. User shall be able to adjust time interval of logged data viewed and shall be able to adjust Y axis of data viewed in graphical format. User shall also be able to download data through the Web interface to local computer. Data shall be in CSV format.

(fffff) G. Alarm Handling

Web interface shall display alarms as they occur. User shall be able to acknowledge alarms using browser technology. In addition, user shall be able to view history of alarm occurrence over a user-selected time frame. In addition, those alarms may be filtered for viewing per user-selected options. A single selection shall display all alarms that have not been acknowledged.

(ggggg) H. Web Page Generation

Web pages shall be automatically generated from the BAS displays that reside on the BAS server. User shall access Web page host through the network and shall initiate a Web page generation utility that automatically takes the BAS displays and turns them into Web pages. The Web pages generated are automatically installed on the Web page host for access using any computer’s standard browser. Any system that requires use of an HTML editor for generation of Web pages shall not be considered.

(hhhhh) I. Password Security and Activity Log

Access through Web browser shall utilize the same hierarchical security scheme as BAS system. User shall be asked to log on once the browser makes connection to Web page host. Once the user logs in, any and all changes that are made shall be tracked by the BAS system. The user shall be able to change only those items he or she has authority to change. A user activity report shall show any and all activity of the users who have logged in to the system, regardless of whether those changes were made using a browser or through the BAS workstation.

(iiiii) J. BACnet Communication

Web server shall directly communicate to all devices on the BAS network using BACnet protocol. No intermediate devices shall be necessary for BACnet communication.

(jjjjj) 2.3 BUILDING CONTROLLER

(kkkkk) A. General Requirements

1. BACnet Conformance

   a. Building Controller shall be approved by the BTL as meeting the BACnet Building Controller requirements.

   b. Please refer to section 22.2, BACnet Functional Groups, in the BACnet standard, for a complete list of the services that must be directly supported to provide each of the functional groups listed above. All proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(lllll) 2. Building controller shall be of scalable design such that the number of trunks and protocols may be selected to fit the specific requirements of a given project.

(mmmmm) 3. The controller shall be capable of panel-mounted on DIN rail and/or mounting screws.

(nnnnn) 4. The controller shall be capable of providing global control strategies for the system based on information from any objects in the system, regardless if the object is directly monitored by the building controller module or by another controller.

(ooooo) 5. The controller shall be capable of running up to six (6) independent control strategies simultaneously. The modification of one control strategy does not interrupt the function or runtime others.

(ppppp) 6. The software program implementing the DDC strategies shall be completely flexible and user-definable. All software tools necessary for programming shall be provided as part of project software. Any systems utilizing factory pre-programmed global strategies that cannot be modified by field personnel on-site, using a wide area network (WAN) or downloaded through remote communications are not acceptable. Changing global strategies using firmware changes is also unacceptable.

(qqqqq) 7. Programming shall be object-oriented using control function blocks and support DDC functions. All flowcharts shall be generated and automatically downloaded to controller. Programming tool shall be supplied and be resident on workstation. The same tool shall be used for all controllers.

(rrrrr) 8. The programming tool shall provide means to graphically view inputs and outputs to each program block in real-time as program is executing. This function may be performed using the operator's workstation or field computer.

(sssss) 9. Controller shall have 6,000 Analog Values and 6,000 Binary Values.

(ttttt) 10. Controller IP configuration can be done via a direct USB connect with an operator's workstation or field computer.

(uuuuu) 11. Controller shall have at a minimum a Quad Core 996Ghz processor to ensure fast processing speeds.

(vvvvv) 12. Global control algorithms and automated control functions shall execute using a 64-bit processor.

(wwwww) 13. Controller shall have a minimum of 1 GB of DDR3 SDRAM on a 533Mhz bus to ensure high speed data recording, large data storage capacity and reliability.

(xxxxx) 14. Controller shall support two (2) on-board EIA-485 ports capable of supporting various EIA-485 protocols including, but not limited to BACnet MS/TP and Modbus.

a. Ports are capable of supporting various EIA-485 protocols including, but not limited to BACnet MS/TP and Modbus.

(yyyyy) 15. Controller shall support two (2) ports—each of gigabit speed—Ethernet (10/100/1000) ports.

a. Ports are capable of supporting various Ethernet protocols including, but not limited to BACnet IP, FOX, and Modbus.

(zzzzz) 16. All ports shall be capable of having protocol(s) assigned to utilize the port's physical connection.

(aaaaaa) 17. The controller shall have at a minimum four (4) onboard inputs, two (2) universal inputs and two (2) binary inputs.

(bbbbbb) 18. Schedules

a. Building controller modules shall provide normal seven-day scheduling, holiday scheduling and event scheduling.

b. Each building controller shall support a minimum of 380 BACnet Schedule Objects and 380 BACnet Calendar Objects.

(cccccc) 19. Logging Capabilities

a. Each building controller shall log as minimum 2,000 objects at 15-minute intervals. Any object in the system (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.

b. Logs may be viewed both on-site or off-site using WAN or remote communication.

c. Building controller shall periodically upload trended data to networked operator's workstation for long-term archiving if desired.

d. Archived data stored in database format shall be available for use in third-party spreadsheet or database programs.

(dddddd) 20. Alarm Generation

a. Alarms may be generated within the system for any object change of value or state (either real or calculated). This includes things such as analog object value changes, binary object state changes, and various controller communication failures.

b. Each alarm may be dialed out as noted elsewhere.

c. Alarm log shall be provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site using remote communications.

d. Controller must be able to handle up to 2,000 alarm setups stored as BACnet event enrollment objects, with system destination and actions individually configurable.

(eeeeee) 21. Demand Limiting

a. Demand limiting of energy shall be a built-in, user-configurable function. Each controller module shall support shedding of up to 1,200 loads using a minimum of two types of shed programs.

b. Load shedding programs in building controller modules shall operate as defined in section 2.1.J of this specification.

(ffffff) 22. Tenant Activity Logging

a. Tenant Activity logging shall be supported by a building controller module. Each independent module shall support a minimum of 380 zones.

b. Tenant Activity logging shall function as defined in section 2.1.K of this specification.

(gggggg) B. BACnet MS/TP

1. BACnet MS/TP LAN must be software-configurable from 9.6 to 115.4Kbps

a. Each BACnet MS/TP LAN shall support 64 BACnet devices at a minimum.

b. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(hhhhhh) C. BACnet IP

1. The building controller shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP internetwork, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the local area network (LAN).

2. Must support interoperability on WANs and campus area networks (CANs), and function as a BACnet Broadcast Management Device (BBMD).

3. Each controller shall support at a minimum 128 BBMD entries.

4. BBMD management architecture shall support 3,000 subnets at a minimum.

5. Shall support BACnet Network Address Translation.

6. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(iiiiii) D. Expansion Ports

1. Controller shall support two (2) expansion ports.

a. Combining the two on-board EIA-458 ports with fully loaded expansion ports, the controller shall support six (6) EIA-485 trunks simultaneously.

(jjjjjj) 2. Expansion cards that mate to the expansion ports shall include:

a. Dual port EIA-485 card.

b. LON network card.

(kkkkkk) E. Niagara Framework

(llllll) 1. Controller shall utilize the Tridium Niagara Framework.

a. Niagara Framework shall be version 3.8 or newer.

b. All Niagara licensing shall be stored on a removable MicroSD card for fast in-field replacement of controller.

(mmmmmm) 2. The Niagara License for the controllers shall be an open license.

a. The controller shall be programmable via Niagara Workplace programming tool.

b. The controller shall be programmable via an Niagara embedded Workplace programming tool.

(nnnnnn) F. Power Supply

(oooooo) 1. Input for power shall accept between 17 and 30VAC, 47 and 63Hz.

(pppppp) 2. Optional rechargeable battery for shutdown of controller including storage of all data in flash memory.

(qqqqqq) 3. On-board capacitor will ensure continuous operation of real-time clocks for minimum of 14 days.

(rrrrrr) G. Controller shall be in compliance with the following:

(ssssss) 1. UL 916 for open energy management

(tttttt) 2. FCC Class B

(uuuuuu) 3. ROHS

(vvvvvv) 4. IEC 60703

(wwwwww) 5. C-Tick Listed

(xxxxxx) H. Controller shall operate in the following environmental conditions:

(yyyyyy) 1. -4 to 149 °F (-20 to 65 °C) without optional battery, or 32 to 122 °F (0 to 50 °C) with optional battery.

(zzzzzz) 2. 0 to 95% relative humidity (RH), non-condensing.

(aaaaaaa) 2.4 CENTRAL PLANT AND AIR HANDLER APPLICATION CONTROLLERS

(bbbbbbb) A. Provide one or more native BACnet application controllers for each air handler and provide native BACnet application controllers as needed for central plant control that adequately cover all objects listed in object list. All controllers shall interface to building controller through either MS/TP LAN using BACnet protocol, or Ethernet LAN using BACnet over Ethernet or BACnet TCP/IP. No gateways shall be used. Controllers shall include input, output and self-contained logic program as needed for complete control of units. Controllers shall be fully programmable using graphical programming blocks. Programming tool shall be resident on operator workstation and be the same tool as used for the building controller. No auxiliary or non-BACnet controllers shall be used.

(ccccccc) B. BACnet Conformance

1. Application controllers shall be approved by the BTL as meeting the BACnet Advanced Application Controller requirements.
2. Please refer to section 22.2, BACnet Functional Groups, in the BACnet standard, for a complete list of the services that must be directly supported to provide each of the functional groups listed above. All proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.
3. Standard BACnet object types supported shall include, as a minimum, Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Multi-state Values, Device, File, and Program object types. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(ddddddd) C. Application controllers shall include universal inputs with 12-bit resolution that accept 3K and 10K thermistors, 0–10VDC, Platinum 1000 ohm RTD, 0–5VDC, 4–20mA and dry contact signals. Any input on a controller may be either analog or digital with a minimum of three inputs that accept pulses. Controller shall also include support and modifiable programming for interface to intelligent room sensor with digital display. Controller shall include binary and analog outputs on board. Analog outputs with 12-bit resolution shall support either 0–10VDC or 0–20mA. Binary outputs shall have LED indication of status. Software shall include scaling features for analog outputs. Application controller shall include 20VDC voltage supply for use as power supply to external sensors.

1. All outputs must have onboard Hand-Off-Auto (HOA) switches and a status indicator light. HOA switch position shall be monitored. Each analog output shall include a potentiometer for manually adjusting the output when the HOA switch is in the Hand position.
2. The position of each and every HOA switch shall be available system wide as a BACnet object property.

(eeeeeee) D. All program sequences shall be stored on board application controller in EEPROM. No batteries shall be needed to retain logic program. All program sequences shall be executed by controller up to 20 times per second (minimum of 10 times per second) and capable of multiple PID loops for control of multiple devices. All calculations shall be completed using floating-point math and system shall support display of all information in floating-point nomenclature at operator’s terminal.

1. The following control blocks shall be supported:
    a. Natural Log
    b. Exponential
    c. Log base 10
    d. 5th Order Polynomial Equations

e. Astronomical Clock (sunrise/sunset calculation)

f. Time based schedules

(fffffff) E. Programming of application controller shall be completely modifiable in the field over installed BACnet LANs or remotely using modem interface. Operator shall program logic sequences by graphically moving function blocks on screen and tying blocks together on screen. Application controller shall be programmed using programming tools as described in operator's terminal section.

(ggggggg) F. Application controller shall include support for intelligent room sensor (see Section 2.10.B.) Display on intelligent room sensor shall be programmable at application controller and include an operating mode and a field service mode. All button functions and display data shall be programmable to show specific controller data in each mode, based on which button is pressed on the sensor. See sequence of operation for specific display requirements at intelligent room sensor.

(hhhhhhh) G. Schedules

1. The controller shall support a minimum of 3 BACnet Schedule Objects and have a real time clock on board with battery backup to maintain time through a power loss.

(iiiiiii) H. Logging Capabilities

1. Controller shall support a minimum of 50 trendlogs. Any object in the controller (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.

2. Controller shall periodically upload trended data to system server for long-term archiving if desired. Archived data stored in (MS Jet Database or SQL) database form and shall be available for use in third-party spreadsheet or database programs.

(jjjjjjj) I. Alarm Generation

1. Alarms may be generated within the controller for any object change of value or state (either real or calculated). This includes things such as analog object value changes, and binary object state changes.

2. Alarm log shall be provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site using remote communications.

3. Controller must be able to handle up to 25 alarm setups stored as BACnet event enrollment objects, with system destination and actions individually configurable.

(kkkkkkk) J. The controller processor shall be a 32-bit processor.

(lllllll) K. The packaging of the controller shall provide operable doors to cover the terminals once installation is complete. The housing of the controller shall provide for DIN rail mounting and also fully enclose circuit board.

(mmmmmmm) **Note to Specifier:** The following section (2.5) is only needed for projects where expandable/standalone central plant and AHU controllers are required. Delete for all other projects.

(nnnnnnn) 2.5 EXPANDABLE CENTRAL PLANT APPLICATION CONTROLLERS

(ooooooo) A. General

1. Expandable application controller shall be capable of providing control strategies for the system based on information from any or all connected inputs. The program that implements these strategies shall be completely flexible and user-definable. Any systems utilizing factory pre-programmed global strategies that cannot be modified by field personnel on-site though simple download are not acceptable. Changing global strategies using firmware changes is also unacceptable. Program execution of controller shall be a minimum of once per second.

2. Programming shall be object-oriented using control program blocks. Controller shall support a minimum of 500 Analog Values and 500 Binary Values. Each and every analog and binary value shall support standard BACnet priority arrays. Programming tool shall be provided with system and shall be the same tool that is used to program the building controller. All flowcharts shall be generated and automatically downloaded to controller. No re-entry of database information shall be necessary.

3. Provide means to graphically view inputs and outputs on each program block in real-time as program is executing. This function may be performed using the operator's terminal or field computer.

4. Controller shall have adequate data storage to ensure high performance and data reliability. Battery shall retain static RAM memory and real-time clock functions for a minimum of 1.5 years (cumulative). Battery shall be a field-replaceable (non-rechargeable) lithium type. Unused battery life shall be 10 years.

5. The onboard, battery-backed real-time clock must support schedule operations and trendlogs.

6. Global control algorithms and automated control functions should execute using 32-bit processor.

7. Controller shall include both onboard 10Base-T/100Base-TX Ethernet BACnet communication over UTP and shall include BACnet IP communication. In addition, controller shall include BACnet Point-to-Point (PTP) connection port.

8. The base unit of the controller shall host up to 8 expansion modules with various I/O combinations. These inputs and outputs shall include universal 12-bit inputs, binary triac outputs, and 8-bit switch-selectable analog outputs (0–10V or 0–20mA). Inputs shall support 3K and 10K thermistors, 0–5VDC, 0–10VDC, 4–20mA, dry contacts and pulse inputs directly.

9. All outputs must have onboard Hand-Off-Auto (HOA) switches and a status indicator light. HOA switch position shall be monitored. Each analog output shall include a potentiometer for manually adjusting the output when the HOA switch is in the Hand position.

10. The position of each and every HOA switch shall be available system wide as a BACnet object. Expandable central plant controller shall provide up to 176 discreet inputs/outputs per base unit.

(ppppppp) B. BACnet Conformance

1. Central plant/AHU controller shall, as a minimum, support PTP, MS/TP and Ethernet BACnet LAN types. It shall communicate directly through these BACnet LANs as a native BACnet device and shall support simultaneous routing functions between all supported LAN types. Controllers shall be approved by the BTL as meeting the BACnet Advanced Application Controller requirements.

2. Please refer to Section 22.2, BACnet Functional Groups, in the BACnet standard, for a complete list of the services that must be directly supported to provide each of the functional groups listed above. All necessary tools shall be supplied for working with proprietary information.

3. Standard BACnet object types supported shall include, as a minimum, Analog Input, Binary Input, Analog Output, Binary Output, Analog Value, Binary Value, Device, File, Group, Event Enrollment, Notification Class, Program, and Schedule object types. All necessary tools shall be supplied for working with proprietary information.

4. The Controller shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP internetwork, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the LAN. Must support interoperability on WANs and CANs, and function as a BBMD.

(qqqqqqq) D. Schedules

1. Each central plant/AHU controller shall support a minimum of 50 BACnet Schedule Objects.

(rrrrrrr) E. Logging Capabilities

1. Each controller shall support a minimum of 200 trendlogs. Any object in the system (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.

2. Controller shall periodically upload trended data to system server for long-term archiving if desired.

3. Archived data stored in database format shall be available for use in third-party spreadsheet or database programs.

(sssssss) F. Alarm Generation

1. Alarms may be generated within the system for any object change of value or state (either real or calculated). This includes things such as analog object value changes, binary object state changes, and various controller communication failures.

2. Alarm log shall be provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site using remote communications.

3. Controller must be able to handle up to 200 alarm setups stored as BACnet event enrollment objects, with system destination and actions individually configurable.

(ttttttt) 2.6 TERMINAL UNIT APPLICATION CONTROLLERS (Heat Pumps, AC Units, Fan-Coils)

(uuuuuuu) A. Provide one native BACnet application controller for each piece of unitary mechanical equipment that adequately covers all objects listed in object list for unit. All controllers shall interface to building controller through MS/TP LAN using BACnet protocol. No gateways shall be used. Controllers shall include input, output and self-contained logic program as needed for complete control of unit.

(vvvvvvv) B. BACnet Conformance

1. Application controllers shall, as a minimum, support MS/TP BACnet LAN types. They shall communicate directly using this BACnet LAN at 9.6, 19.2, 38.4 and 76.8 Kbps, as a native BACnet device. Application controllers shall be approved by the BTL as meeting the BACnet Application Specific Controller requirements and support all BACnet services necessary to provide the following BACnet functional groups:

   a. Files Functional Group

   b. Reinitialize Functional Group

   c. Device Communications Functional Group

2. Please refer to Section 22.2, BACnet Functional Groups in the BACnet standard, for a complete list of the services that must be directly supported to provide each of the functional groups listed above. All proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

3. Standard BACnet object types supported shall include, as a minimum, Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Device, File, and Program Object Types. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(wwwwwww) C. Application controllers shall include universal inputs with 10-bit resolution that can accept 3K and 10K thermistors, 0–5VDC, 4–20mA, dry contact signals and a minimum of 3 pulse inputs. Any input on controller may be either analog or digital. Controller shall also include support and modifiable programming for interface to intelligent room sensor. Controller shall include binary outputs on board with analog outputs as needed.

(xxxxxxx) D. All program sequences shall be stored on board controller in EEPROM. No batteries shall be needed to retain logic program. All program sequences shall be executed by controller 10 times per second and shall be capable of multiple PID loops for control of multiple devices. Programming of application controller shall be completely modifiable in the field over installed BACnet LANs or remotely through modem interface. Operator shall program logic sequences by graphically moving function blocks on screen and tying blocks together on screen. Application controller shall be programmed using same programming tools as building controller and as described in operator workstation section. All programming tools shall be provided and installed as part of system.

(yyyyyyy) E. Application controller shall include support for intelligent room sensor (see Section 2.10.B.) Display on room sensor shall be programmable at controller and include an operating mode and a field service mode. All button functions and display data shall be programmable to show specific controller data in each mode based on which button is pressed on the sensor. See sequence of operation for specific display requirements at intelligent room sensor.

(zzzzzzz) **Note to Specifier:** The following section (2.7) is only needed for projects where wireless MS/TP is required. You will need to use the AZW-5000 to meet the intent of this section. Delete for all other projects.

(aaaaaaaa) 2.7 WIRELESS MS/TP TRANSCEIVER

(bbbbbbbb) A. BACnet Conformance

1. Wireless MS/TP Transceiver shall meet BACnet Addendum q of ANSI/ASHRAE 135-2008 requirements.

2. Support multiple BACnet Application Specific Controllers (B-ASC) to a Transceiver MS/TP trunk.

3. Support multi-transceiver mesh wireless network topology

4. Wireless MS/TP Transceiver shall, at a minimum, support MS/TP BACnet LAN types. They shall communicate directly through this BACnet LAN at 9.6, 19.2, 38.4 and 76.8 Kbps, as a B-ASC BACnet device.

5. Standard BACnet object types supported shall include, as a minimum, Analog Value, Binary Value, Device, File, and Program Object Types.

6. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(cccccccc) B. Wireless MS/TP Transceiver hardware shall:

1. Include a 32 Bit processor

2. Include two selectable internal antennae with perpendicular orientation

3. Support external antenna using industry standard SMA connector type

4. Support connection to 2.4 GHz (IEEE Std 802.15.4-2003 compliant) Wireless Wall Sensors (Battery powered).

5. Meet the requirements of Listed Underwriters Laboratory for Open Energy Management Equipment (PAZX) under the UL Standard for Safety 916.

6. Meet the requirements of EMC Directive (European CE Mark) EN 60950.

7. Meet the requirements for FCC Part 15, Class B.

8. Meet the requirements for EU Wireless: EN300328-1 2.4 GHz Spread Spectrum, EN301489-1:2000 Standard.

9. Be powered by 24VAC power.

(dddddddd) C. Wireless MS/TP Transceiver firmware shall:

1. All configuration and point data shall be stored on board transceiver in Flash Memory.

2. No batteries shall be needed to retain configuration data.

3. Configuration of Wireless MS/TP Transceiver shall be completely modifiable in the field over installed BACnet LANs or remotely using modem interface.

4. Wireless MS/TP communication shall be encrypted to 128 bit AES encryption standard.

(eeeeeeee) D. Wireless wall sensors shall be supported by the Wireless MS/TP Transceiver

1. Support up to Fifty (50) wireless wall sensors simultaneously.

2. Wireless wall sensors shall operate in the 2.4 GHz (IEEE Std 802.15.4-2003 compliant) radio frequency

3. Support temperature, temperature and humidity, and temperature, setpoint and after-hours override wireless wall sensor types.

4. Wireless communication shall be encrypted to 128 bit AES encryption standard

(ffffffff) E. Wireless Wall Sensor

1. Wireless wall sensor shall use solid-state sensor(s) and shall be packaged in aesthetically pleasing enclosure.

2. Sensor shall provide override function, warmer/cooler dial for set point adjustment. Override time shall be stored in controller and be adjustable on a zone-by-zone basis. Adjustment range for warmer/cooler lever shall also be stored in EEPROM on controller.

3. There shall be a mechanical means the lock the wall sensor to the base to prevent theft and vandalism

4. The wireless range in open air shall meet or exceed 300 ft. The strength of the wireless signal must be indicated at the wireless sensor to aid in placement and trouble shooting.

5. The receiver shall have a wireless communications received light that indicates the proper communication is occurring.

6. The wireless wall sensor and receiver must be paired in an addressable mean to facilitate easy replacement and reassignment.

7. Temperature shall be accurate to +/- 0.5 degree Celsius from 12–30 degrees Celsius.

8. Humidity sensor shall be accurate to +/-3% RH from 11-89% RH.

9. Shall run on two AA Lithium batteries; providing a minimum battery life of 5 years. Low battery power shall be indicated on the unit via an LED and also readable as a BACnet Object.

10. Shall use 2.4 GHz radio frequency (IEEE Std 802.15.4-2003 compliant)

11. Wireless communication shall be encrypted to 128 bit AES encryption standard.

(gggggggg) 2.8 VAV BOX CONTROLLERS—SINGLE DUCT

(hhhhhhhh) A. Provide one native BACnet application controller for each VAV box that adequately covers all objects listed in object list for unit. All controllers shall interface to building controller through MS/TP LAN using BACnet protocol. No gateways shall be used. Controllers shall include on board CFM flow sensor, inputs, outputs and programmable, self-contained logic program as needed for control of units.

(iiiiiii) B. BACnet Conformance

1. Application controllers shall, at a minimum, support MS/TP BACnet LAN types. They shall communicate directly through this BACnet LAN at 9.6, 19.2, 38.4 and 76.8 Kbps, as a native BACnet device. Application controllers shall be approved by the BTL as meeting the BACnet Application Specific Controller requirements.

2. Please refer to Section 22.2, BACnet Functional Groups, in the BACnet standard, for a complete list of the services that must be directly supported to provide each of the functional groups listed above. All proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

3. Standard BACnet object types supported shall include, as a minimum, Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Device, File, and Program Object Types. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(jjjjjjj) C. Application controllers shall include universal inputs with 10-bit resolution that can accept 3K and 10K thermistors, 0–5 VDC, and dry contact signals. Inputs on controller may be either analog or digital. Controller shall also include support and modifiable programming for interface to intelligent room sensor with digital display. Controller shall also include binary outputs on board. For applications using variable speed parallel fans, provide a single analog output selectable for 0-10 V or 0-20 mA control signals. Application controller shall include microprocessor driven flow sensor for use in pressure independent control logic. All boxes shall be controlled using pressure-independent control algorithms and all flow readings shall be in CFM (LPS if metric).

(kkkkkkkk) D. All program sequences shall be stored on board application controller in EEPROM. No batteries shall be needed to retain logic program. All program sequences shall be executed by controller 10 times per second and shall be capable of multiple PID loops for control of multiple devices. Programming of application controller shall be completely modifiable in the field over installed BACnet LANs or remotely using modem interface. Operator shall program logic sequences by graphically moving function blocks on screen and tying blocks together on screen. Application controller shall be programmed using the same programming tool as Building Controller and as described in operator's workstation section. All programming tools shall be provided as part of system.

(lllllll) E. Application controller shall include support for intelligent room sensor (see Section 2.10.B.) Display on room sensor shall be programmable at application controller and include an operating mode and a field service mode. All button functions and display data shall be programmable to show specific controller data in each mode based on which button is pressed on the sensor. See sequence of operations for specific display requirements for intelligent room sensor.

(mmmmmmmm) F. On board flow sensor shall be microprocessor-driven and pre-calibrated at the factory. Pre-calibration shall be at 16 flow points as a minimum. All factory calibration data shall be stored in non-volatile memory. Calibration data shall be field adjustable to compensate for variations in VAV box type and installation. All calibration parameters shall be adjustable through intelligent room sensor. Operator's workstation, portable computers, and special hand-held field tools shall not be needed for field calibration.

(nnnnnnnn) G. Provide duct temperature sensor at discharge of each VAV box that is connected to controller for reporting back to operator's workstation.

(oooooooo) **Note to Specifier:** The following section (2.9) is only needed for projects where VLD-362,
VLD-362-FF or VLD-362W controllers are required. You will need to use the VLD-362W and appropriate sensors to meet the wireless section. Delete for all other projects.

(pppppppp) 2.9 TOUCH SCREEN COMMUNICATING THERMOSTAT

(qqqqqqqq) A. BACnet Conformance

1. Touch screen communicating thermostats shall be approved by the BTL as meeting the BACnet Application Specific Controller requirements.
2. Touch screen Communicating Thermostats shall, at a minimum, support MS/TP BACnet LAN types. They shall communicate directly through this BACnet LAN at 9.6, 19.2, 38.4 and 76.8 Kbps, as a native BACnet device.
3. Standard BACnet object types supported shall include, as a minimum, Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Device, File, and Program Object Types.
4. All proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

(rrrrrrrr) B. Touch screen Communicating Thermostat hardware shall:

1. Include a 32 Bit processor
2. Include a backlit touch screen for the user interface, buttons are not allowed.
3. Include Three (3) universal inputs with 12-bit resolution that can accept 3K and 10K Type II thermistors, 0-10VDC, 0–5 VDC, 4-20mA, and dry contact signals. Inputs on controller may be either analog or digital.
4. Include built-in temperature sensor.
5. Include built-in humidity sensor.
6. Include Six (6) relay outputs on board.
7. Include Two (2) analog outputs with 12-bit resolution. Each auto-detecting for 0-10 V or 4-20 mA control signals.
8. Meet the requirements of Listed Underwriters Laboratory for Open Energy Management Equipment (PAZX) under the UL Standard for Safety 916.
9. Meet the requirements of EMC Directive (European CE Mark) EN 60950.
10. Meet the requirements for FCC Part 15, Class B.
11. Be powered by 24VAC power.

(ssssssss)

(tttttttt) **Note to Specifier:** The following section C should be deleted for VLD-362-FF. Leave Section C for VLD-362 and VLD-362W.

(uuuuuuuu) A. Touch screen Communicating Thermostat programming shall:

1. All program sequences shall be stored on board application controller in Flash Memory.
2. No batteries shall be needed to retain logic program.
3. All program sequences shall be executed by controller 10 times per second and shall be capable of multiple PID loops for control of multiple devices.

4. Support internal schedule with real time clock.

5. Support Peer-to-Peer programming.

6. Support lockout of touch screen with a pass code.

7. Programming of application controller shall be completely modifiable in the field over installed BACnet LANs or remotely using modem interface.

8. Operator shall program logic sequences by graphically moving function blocks on screen and tying blocks together on screen.

9. Application controller shall be programmed using the same programming tool as Building Controller and as described in operator's workstation section. All programming tools shall be provided as part of system.

(vvvvvvvv) **Note to Specifier:** The following section D is only needed for projects where VLD-362W controllers are required. You will need to use the VLD-362W and appropriate sensors to meet the wireless section. Delete for all other projects.

(wwwwwwww) A. Wireless sensors shall be supported by the Touch screen Communicating Thermostat

1. Support up to eight (8) magnetic contact switches with CR2032-battery powered wireless transmitter.

2. Support up to three (3) passive infrared (PIR) motion detectors with 140-degree detection angle and AAA battery-powered wireless transmitter.

3. Meet the requirements for FCC Part 15, Class B.

4. Individual wireless sensor inputs can be used by fully programmable DDC to create custom sequence of operations in controller.

5. Sensors operate in the 433.92 MHz wireless frequency with 50-foot range.

(xxxxxxxx) 2.10 AUXILIARY CONTROL DEVICES

(yyyyyyyy) A. Temperature Sensors

1. All temperature sensors to be solid-state electronic, interchangeable with housing appropriate for application. Wall sensors to be installed as indicated on drawings. Mount 48 inches above finished floor. Duct sensors to be installed such that the sensing element is in the main air stream. Immersion sensors to be installed in wells provided by control contractor, but installed by mechanical contractor. Immersion wells shall be filled with thermal compound before installation of immersion sensors. Outside air sensors shall be installed away from exhaust or relief vents, not in an outside air intake, and in a location that is in the shade most of the day.

(zzzzzzzz) B. Intelligent Room Sensor with Touchscreen (optional if specifying Micro set 4 with MS/TP or CO2, but not both)

1. Hardware

   a. Room sensor shall include:

      i. Backlit touchscreen LCD digital display

      ii. Temperature sensor

      iii. Humidity sensor

      iv. Programmable Status Light indicator

      v. CO2 sensor or BACnet MS/TP communication up to 115.2kbps

(i) b. Temperature sensor shall be a Uni-Curve Type II thermistor with an accuracy of +/- 0.36 °F (0.3 °C) at calibration point over the range of 32 to 158 °F or better.

(ii) c. Humidity sensor shall have an accuracy of +/-3% from 10 to 90% relative humidity (RH) or better, non-condensing.

(iii) d. The intelligent room sensor's Status Light indicator shall have a minimum of four (4) colors (blue, red, amber and green) that will cast a glow onto the wall below the sensor to be used as visual indicator to the occupants of the condition of the system. The color and on/off state of the Status Light indicator shall be fully programmable.

(iv) e. CO2 sensor shall have an accuracy of +/- 30 ppm over the range of 0–5000 ppm or better.

(v) f. CO2 sensor shall utilize Automatic Baseline Correction to maintain sensor calibration without the need for manual calibration.

(vi) g. The user shall interact with the smart sensor using a touchscreen, with no buttons allowed.

(vii) h. The intelligent room sensor shall have provisions for a tamper proof installation requiring tools to be removed from the wall.

(viii) i. The touchscreen shall have a surface hardness of Mohs 7 or greater to prevent being easily scratched.

(ix) j. Controller shall function as room control unit, and allow occupant to raise and lower setpoint, and activate terminal unit for override use—all within limits as programmed by building operator.

(aaaaaaaaa) 2. Display Content

(i) a. The intelligent room sensor shall simultaneously display room setpoint, room temperature, and outside temperature at each controller.

(ii) b. The intelligent room sensor shall have the ability to add or remove from the display time-of-day, room humidity, and indoor air temperature to customize the view for the customer.

(iii) c. The intelligent room sensor must have the capability to show temperatures in degrees Fahrenheit or degrees Celsius.

(iv) d. A communication loss or improper communications wiring shall be displayed on the LCD screen to aid in trouble shooting.

(v) e. Information about the version of firmware shall be displayable on the LCD screen.

(vi) f. A cleaning mode will be provided to allow for the touchscreen to be cleaned without inadvertently making changes to system parameters.

(vii) g. The intelligent room sensor shall have the ability to display the status of a lighting zone and control the on/off state of the zone from the touchscreen using a tenant-accessible display page.

(viii) h. The intelligent room sensor shall have the ability to display the status of a window zone (e.g., blinds) and control the on/off state of the zone from the touchscreen using a tenant-accessible display page.

(ix) i. After Hours Override shall:

vi. Override time may be set and viewed in 30-minute increments.

vii. Override time countdown shall be automatic, but may be reset to zero by occupant from the sensor.

viii. Time remaining shall be displayed.

ix. Display shall show the word “OFF” in unoccupied mode unless a function button is pressed.

(bbbbbbbbb) 3. Other Modes

(i) a. The intelligent room sensor shall also allow service technician access to hidden functions for advanced system configuration. This functionality shall be accessed-protected with a configurable PIN number.

(ii) b. Field Service Mode shall allow access to common parameters as dictated by the application’s sequence of operations. The parameters shall be viewed and set from the intelligent room sensor with no computer or other field service tool needed.

(iii) c. If the intelligent room sensor is connected to VAV controller, Balance Mode shall allow a VAV box to be balanced and all air flow parameters viewed. The balancing parameters shall be viewed and set from the intelligent room sensor with no computer or other field service tool needed.

(ccccccccc) 4. Intelligent Room Sensor shall be in compliance of the following:

(i) a. UL Standard for Safety 916

(ii) b. FCC Part 15.107 & 109, Class B, CFR47-15

(iii) c. EMC Directive 89/336/EEC (European CE Mark)

(ddddddddd) 2.11 ELECTRONIC ACTUATORS AND VALVES (insert as required, sample requirements follow)

(eeeeeeeee) A. Quality Assurance for Actuators and Valves

1. UL Listed Standard 873 and C.S.A. Class 4813 02 certified.

2. NEMA 2 rated enclosures for inside mounting, provide with weather shield for outside mounting.

3. Five-year manufacturer’s warranty. Two-year unconditional and three-year product defect from date of installation.

(fffffffff) B. Execution Details for Actuators and Valves

1. Furnish a Freeze-stat and install “Hard Wire” interlock to disconnect the mechanical spring return actuator power circuit for fail-safe operation. Use of the control signal to drive the actuators closed is not acceptable.

2. Each DDC analog output point shall have an actuator feedback signal, independent of control signal, wired and terminated in the control panel for true position information and troubleshooting. Or the actuator feedback signal may be wired to the DDC as an analog input for true actuator position status.

3. VAV box damper actuation shall be floating type or analog (2–10VDC, 4–20mA).

4. Booster-heat valve actuation shall be floating type or analog (2-10vdc, 4-20ma).

5. Primary valve control shall be analog (2–10VDC, 4–20mA).

(ggggggggg) C. Actuators for damper and control valves 0.5–6 inches shall be electric unless otherwise specified, provide actuators as follows:

1. UL Listed Standard 873 and Canadian Standards association Class 481302 shall certify actuators.

2. NEMA 2 rated actuator enclosures for inside mounting. Use additional weather shield to protect actuator when mounted outside.

3. Five-year manufacturer's warranty. Two-year unconditional and Three year product defect from date of installation.

4. Mechanical spring shall be provided when specified. Capacitors or other non-mechanical forms of fail-safe are not acceptable.

5. Position indicator device shall be installed and made visible to the exposed side of the actuator. For damper short shaft mounting, a separate indicator shall be provided to the exposed side of the actuator.

6. Overload Protection: Actuators shall provide protection against actuator burnout by using an internal current limiting circuit or digital motor rotation sensing circuit. Circuit shall insure that actuators cannot burn out due to stalled damper or mechanical and electrical paralleling. End switches to deactivate the actuator at the end of rotation are acceptable only for butterfly valve actuators.

7. A Pushbutton gearbox release shall be provided for all non-spring actuators.

8. Modulating actuators shall be 24VAC and consume 10VA power or less.

9. Conduit connectors are required when specified and when code requires it.

(hhhhhhhhh) D. Damper Actuators:

1. Outside air and exhaust air damper actuators shall be mechanical spring return. Capacitors or other non-mechanical forms of fail-safe are not acceptable. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the damper as required.

2. Economizer actuators shall utilize analog control 2–10VDC, floating control is not acceptable.

3. Electric damper actuators (including VAV box actuators) shall be direct shaft-mounted and use a V-bolt and toothed V-clamp causing a cold weld effect for positive gripping. Single bolt or set-screw type fasteners are not acceptable.

4. One electronic actuator shall be direct shaft-mounted per damper section. No connecting rods or jackshafts shall be needed. Small outside air and return air economizer dampers may be mechanically linked together if one actuator has sufficient torque to drive both and damper drive shafts are both horizontal installed.

5. Multi-section dampers with electric actuators shall be arranged so that each damper section operates individually. One electronic actuator shall be direct shaft-mounted per damper section. (See below execution section for more installation details.)

(iiiiiiiii) E. Valve Actuators 0.5–6 inches

1. Mechanical spring shall be provided on all actuators for pre-heat coil and actuators for AHU heating or cooling coil when units are mounted outside. See plans for fail-safe flow function: Normal Open or Normal Closed. Capacitors or other non-mechanical forms of fail-safe are not acceptable.

2. All zone service actuators shall be non-spring return unless otherwise specified.

3. The valve actuator shall be capable of providing the minimum torque required for proper valve close-off for the required application.

4. All control valves actuators shall have an attached 3-foot cable for easy installation to a junction box.

5. Override handle and gearbox release shall be provided for all non-spring return valve actuators.

(jjjjjjjjj) F. Control Dampers.

(kkkkkkkkk) **Note to Specifier:** Pick either BAS or sheet metal contractor.

1. The BAS contractor or sheet metal contractor shall furnish and size all automatic control dampers unless provided with packaged equipment. The sheet metal contractor shall install all dampers unless provided with packaged equipment.

2. All dampers used for modulating service shall be opposed blade type and arranged for normally open or normally closed operation as required. The damper is to be sized so that, when wide open, the pressure drop is a sufficient amount of its close-off pressure drop for effective throttling.

3. All dampers used for two-position or open-close control shall be parallel blade type arranged for normally open or closed operation as required.

4. Damper linkage hardware shall be constructed of aluminum or corrosion-resistant zinc and nickel-plated steel and furnished as follows:

5. Bearing support bracket and drive blade pin extension shall be provided for each damper section. Sheet metal contractor shall install bearing support bracket and drive blade pin extension. Sheet metal contractor shall provide permanent indication of blade position by scratching or marking the visible end of the drive blade pin extension.

6. Drive pin may be round only if V-bolt and toothed V-clamp is used to cause a cold weld effect for positive gripping. For single bolt or set-screw type actuator fasteners, round damper pin shafts must be milled with at least one side flat to avoid slippage.

7. Damper manufacturer shall supply alignment plates for all multi-section dampers.

(lllllllll) G. Control Valves 0.5–6 inches

1. The BAS contractor shall furnish all specified motorized control valves and actuators. BAS contractor shall furnish all control wiring to actuators. The plumbing contractor shall install all valves. Equal percentage control characteristic shall be provided for all water coil control valves. Linear valve characteristic is acceptable for 3-way valves that are 2.5 inches and above.

2. Characterized control valves shall be used for hydronic heating or cooling applications and small to medium AHU water-coil applications to 100GPM. Actuators are non-spring return for terminal unit coil control unless otherwise noted. If the coil is exposed to the outside air stream, see plans for spring return requirement.

   a. Leakage is aero percent, close-off is 200psi, maximum differential is 30psi; rangeability is 500:1.

   b. Valves 0.5–2 inches shall be nickel-plated forged brass body, NPT screw type connections.

   c. Valves 0.5–1.25 inches shall be rated for ANSI Class 600 working pressure. Valves 1.5 and 2 inches shall be rated for ANSI Class 400 working pressure.

   d. The operating temperature range shall be 0–250 degrees F.

   e. Stainless steel ball and stem shall be furnished on all modulating valves.

   f. Seats shall be fiberglass reinforced Teflon.

   g. Two-way and three-way valves shall have an equal percentage control port. Full stem rotation is required for maximum flow to insure stable BTU control of the coil.

   h. Three-way valve shall be applicable for both mixing and diverting.

   i. The characterizing disc is made of TEFZEL and shall be keyed and held secure by a retaining ring.

j. The valves shall have a blow-out proof stem design.

k. The stem packing shall consist of 2 lubricated O-rings designed for on-off or modulating service and require no maintenance.

l. The valves shall have an ISO type, 4-bolt flange for mounting actuator in any orientation parallel or perpendicular to the pipe.

m. A non-metallic thermal isolation adapter shall separate valve flange from actuator.

n. One fastening screw shall secure the direct coupling of the thermal isolation adapter between the actuator and the valve. This will prevent all lateral or rotational forces from affecting the stem and its packing O-rings.

3. Globe valves 0.5–2 inches shall be used for steam control or water flow applications.

a. Valves shall be bronze body, NPT screw type, and shall be rated for ANSI Class 250 working pressure.

b. Valves 0.5 inches (DN15) through 2 inches (DN50) with spring return actuators shall close off against 50 psi pressure differential with Class III leakage (0.1%).

c. The operating temperature range shall be 20–280 degrees F.

d. Spring loaded TFE packing shall protect against leakage at the stem.

e. Two-way valves shall have an equal percentage control port.

f. Three-way valves shall have a linear control and bypass port.

g. Mixing and diverting valves must be installed specific to the valve design.

4. Globe Valve 2.5–6 inches

a. Valves 2.5 inches (DN65) through 6 inches (DN50) shall be iron body, 125 lb. flanged with Class III (0.1%) close-off leakage at 50 psi differential.

b. Valves with spring return actuators shall close off against 50 psi pressure differential with Class III leakage (0.1%).

c. Flow type for two-way valves shall be equal percentage. Flow type for three-way valves shall be linear.

d. Mixing and diverting valves must be installed specific to the valve design.

(mmmmmmmmm) H. Butterfly valves

1. Butterfly valves shall be sized for modulating service at 60–70 degree stem rotation. Isolation valves shall be line-size. Design velocity shall be less than 12 feet per second when used with standard EPDM seats.

a. Body is cast iron.

b. Disc is aluminum bronze standard.

c. Seat is EPDM standard.

d. Body Pressure is 200 psi, -30–275 degrees F.

e. Flange is ANSI 125/250.

f. Media Temperature Range is -22–240 degree F.

g. Maximum Differential Pressure is 200 psi for 2- to 6- inch size.

(nnnnnnnnn) I. Butterfly Valve Industrial Actuators

1. Actuators shall be approved under Canadian Standards Association or other Nationally Recognized Testing Laboratory to UL standards. CSA Class 4813 02 or equal. Enclosure shall be NEMA 4 (weatherproof) enclosure and will have an industrial quality coating.

    a. Actuator shall have a motor rated for continuous duty. The motor shall be fractional horsepower; permanent split capacitor type designed to operate on a 120VAC, 1pH, 60Hz supply. Two adjustable cam-actuated end travel limit switches shall be provided to control direction of travel. A self-resetting thermal switch shall be imbedded in the motor for overload protection.

    b. Reduction gearing shall be designed to withstand the actual motor stall torque. Gears shall be hardened alloy steel, permanently lubricated. A self-locking gear assembly or a brake shall be supplied.

    c. Actuator shall have a 6 ft wiring harness provided for ease in field wiring (above 1500 in-lbs). Two adjustable SPDT cam-actuated auxiliary switches, rated at 250VAC shall be provided for indication of open and closed position. Actuator shall have heater and thermostat to minimize condensation within the actuator housing.

    d. Actuator shall be equipped with a hand wheel for manual override to permit operation of the valve in the event of electrical power failure or system malfunction. Hand wheel must be permanently attached to the actuator and when in manual operation electrical power to the actuator will be permanently interrupted. The hand wheel will not rotate while the actuator is electrically driven.

    e. The actuator shall be analog, floating, or two position as called out in the control sequence of operation. All Analog valves shall be positive positioning, and respond to a 2–10VDC, 4-20mA, or adjustable signal as required. Analog actuators shall have a digital control card allowing any voltage input for control and any DC voltage feedback signal for position indication.

2. Performance Verification Test

    a. Control loops shall cause productive actuation with each movement of the actuator and actuators shall modulate at a rate that is stable and responsive. Actuator movement shall not occur before the effects of previous movement have affected the sensor.

    b. Actuator shall have capability of signaling a trouble alarm when the actuator Stop-Go Ratio exceeds 30%.

3. Actuator mounting for damper and valve arrangements shall comply to the following:

    a. Damper actuators: Shall not be installed in the air stream

    b. A weather shield shall be used if actuators are located outside. For damper actuators, use clear plastic enclosure.

    c. Damper or valve actuator ambient temperature shall not exceed 122 degrees F through any combination of medium temperature or surrounding air. Appropriate air gaps, thermal isolation washers or spacers, standoff legs, or insulation shall be provided as necessary.

    d. Actuator cords or conduit shall incorporate a drip leg if condensation is possible. Water shall not be allowed to contact actuator or internal parts. Location of conduits in temperatures dropping below dew point shall be avoided to prevent water from condensing in conduit and running into actuator.

    e. Damper mounting arrangements shall comply to the following:

        x. The ventilation subcontractor shall furnish and install damper channel supports and sheet metal collars.

xi. No jack shafting of damper sections shall be allowed.

xii. Multi-section dampers shall be arranged so that each damper section operates individually. One electronic actuator shall be direct shaft mounted per section.

f. Size damper sections based on actuator manufacturer's specific recommendations for face velocity, differential pressure and damper type. In general:

i. Damper section shall not exceed 24 ft-sq. with face velocity >1500 FPM.

i. Damper section shall not exceed 18 ft-sq. with face velocity > 2500 FPM.

ii. Damper section shall not exceed 13 ft-sq. with face velocity > 3000 FPM.

g. Multiple section dampers of two or more shall be arranged to allow actuators to be direct shaft mounted on the outside of the duct.

h. Multiple section dampers of three or more sections wide shall be arranged with a 3-sided vertical channel (8 inches wide by 6 inches deep) within the duct or fan housing and between adjacent damper sections. Vertical channel shall be anchored at the top and bottom to the fan housing or building structure for support. The sides of each damper frame shall be connected to the channels. Holes in the channel shall allow damper drive blade shafts to pass through channel for direct shaft-mounting of actuators. Open side of channel shall be faced downstream of the airflow, except for exhaust air dampers.

i. Multiple section dampers to be mounted flush within a wall or housing opening shall receive either vertical channel supports as described above or sheet metal standout collars. Sheet metal collars (12-inch minimum) shall bring each damper section out of the wall to allow direct shaft-mounting of the actuator on the side of the collar.

4. Valve Sizing for Water Coil

a. On/Off control valves shall be line size.

b. Modulating control valve body size may be reduced, at most, two pipe sizes from the line size or not less than half the pipe size. The BAS contractor shall size all water coil control valves for the application as follows:

i. Booster-heat valves shall be sized not to exceed 4–9psi differential pressure. Size valve for 50% valve authority. Valve design pressure drop is equal to the sum of coil drop plus the balance valve drop.

ii. Primary valves shall be sized not to exceed 5–15psi differential pressure. Size valve for 50% valve authority. Valve design pressure drop is equal to the sum of coil drop plus the balance valve drop.

iii. Butterfly valves shall be sized for modulating service at 60–70 degree rotation. Design velocity shall be 12 feet per second or less when used with standard EPDM seats.

c. Valve mounting arrangements shall comply to the following:

i. Unions shall be provided on all ports of two-way and three-way valves.

ii. Install three-way equal percentage characterized control valves in a mixing configuration with the "A" port piped to the coil.

iii. Install 2.5 inches and above, three-way globe valves, as manufactured for mixing or diverting service to the coil.

(ooooooooo) 2.12 ENCLOSURES

(ppppppppp) A. All controllers, power supplies and relays shall be mounted in enclosures.

(qqqqqqqqq) B. Enclosures may be NEMA 1 when located in a clean, dry, indoor environment. Indoor enclosures shall be NEMA 12 when installed in other than a clean environment.

(rrrrrrrrr) C. Enclosures shall have hinged, locking doors.

(sssssssss) D. Provide laminated plastic nameplates for all enclosures in any mechanical room or electrical room. Include location and unit served on nameplate. Laminated plastic shall be 0.125 inches thick and appropriately sized to make label easy to read.

PART 79 - PART 3: EXECUTION

(tttttttt) 3.1 EXAMINATION

(uuuuuuuuu) A. Prior to starting work, carefully inspect installed work of other trades and verify that such work is complete to the point where work of this Section may properly commence.

(vvvvvvvvv) B. Notify the owner's representative in writing of conditions detrimental to the proper and timely completion of the work.

(wwwwwwwwww)C. Do not begin work until all unsatisfactory conditions are resolved.

(xxxxxxxxx) 3.2 INSTALLATION (GENERAL)

(yyyyyyyyy) A. Install in accordance with manufacturer's instructions.

(zzzzzzzzz) B. Provide all miscellaneous devices, hardware, software, interconnections, installation, and programming required to ensure a complete operating system in accordance with the sequences of operation and point schedules.

(aaaaaaaaaa) 3.3 LOCATION AND INSTALLATION OF COMPONENTS

(bbbbbbbbbb) A. Locate and install components for easy accessibility; in general, mount 48 inches above floor with minimum 3 feet of clear access space in front of units. Obtain approval on locations from owner's representative prior to installation.

(cccccccccc) B. All instruments, switches, transmitters, etc., shall be suitably wired and mounted to protect them from vibration, moisture, and high or low temperatures.

(dddddddddd) C. Identify all equipment and panels. Provide permanently mounted tags for all panels.

(eeeeeeeeee) D. Provide stainless steel or brass thermowells suitable for respective application and for installation under other sections, and sized to suit pipe diameter without restricting flow.

(ffffffffff) 3.4 INTERLOCKING AND CONTROL WIRING

(gggggggggg) A. Provide all interlock and control wiring. All wiring shall be installed neatly and professionally, in accordance with Specification Division 16 and all national, state and local electrical codes.

(hhhhhhhhhh) B. Provide wiring as required by functions as specified and as recommended by equipment manufacturers, to serve specified control functions. Provide shielded low capacitance wire for all communications trunks.

(iiiiiiiiii) C. Control wiring shall not be installed in power circuit raceways. Magnetic starters and disconnect switches shall not be used as junction boxes. Provide auxiliary junction boxes as required. Coordinate location and arrangement of all control equipment with the owner's representative prior to rough-in.

(jjjjjjjjjj) D. Provide auxiliary pilot duty relays on motor starters as required for control function.

(kkkkkkkkkk) E. Provide power for all control components from nearest electrical control panel or as indicated on the electrical drawings; coordinate with electrical contractor.

(llllllllll) F. All control wiring in the mechanical, electrical, telephone and boiler rooms to be installed in raceways. All other wiring to be installed neatly and inconspicuously per local code requirements. If local code allows, control wiring above accessible ceiling spaces may be run with plenum-rated cable (without conduit).

(mmmmmmmmmm) 3.5 DDC OBJECT TYPE SUMMARY

(nnnnnnnnnn) A. Provide all database generation.

(oooooooooo) B. Displays

1. System displays shall show all analog and binary object types within the system. They shall be logically laid out for easy use by the owner. Provide outside air temperature indication on all system displays associated with economizer cycles.

(pppppppppp) C. Run Time Totalization

1. At a minimum, run time totalization shall be incorporated for each monitored supply fan, return fan, exhaust fan, hot water and chilled water pumps. Warning limits for each point shall be entered for alarm and or maintenance purposes.

(qqqqqqqqqq) D. Trendlog

1. All binary and analog object types (including zones) shall have the capability to be automatically trended.

(rrrrrrrrrr) E. Alarm

1. All analog inputs (High/Low Limits) and selected binary input alarm points shall be prioritized and routed (locally or remotely) with alarm message per owner's requirements.

(ssssssssss) F. Database Save

1. Provide backup database for all standalone application controllers on disk.

(tttttttttt) 3.6 FIELD SERVICES

(uuuuuuuuuu) A. Prepare and start logic control system under provisions of this section.

(vvvvvvvvvv) B. Start up and commission systems. Allow sufficient time for startup and commissioning prior to placing control systems in permanent operation.

(wwwwwwwwww) C. Provide the capability for off-site monitoring at control contractor's local or main office. At a minimum, off-site facility shall be capable of system diagnostics and software download. Owner shall provide phone line for this service for one year or as specified.

(xxxxxxxxxx) D. Provide owner's representative with spare parts list. Identify equipment critical to maintaining the integrity of the operating system.

(yyyyyyyyyy) 3.7 AS-BUILT DOCUMENTATION REQUIRED

(zzzzzzzzzz) A.

(aaaaaaaaaaa) 3.8 TRAINING

(bbbbbbbbbbb) A. Provide application engineer to instruct owner in operation of systems and equipment.

(ccccccccccc) B. Provide system operator’s training to include (but not be limited to) such items as the following: modification of data displays, alarm and status descriptors, requesting data, execution of commands and request of logs. Provide this training to a minimum of three persons.

(ddddddddddd) C. Provide on-site training above as required, up to 16 hours as part of this contract.

(eeeeeeeeeee) D. Provide tuition for at least one individual to attend for a one-week factory training class. If applicable, costs for travel, lodging and meals will be the responsibility of the owner.

(fffffffffff) 3.9 DEMONSTRATION

(ggggggggggg) A. Demonstrate complete operating system to owner's representative.

(hhhhhhhhhhh) B. Provide certificate stating that control system has been tested and adjusted for proper operation.

XXX. NON-METAL DUCTS

PART 80 - PART 1 - GENERAL

80.1 SUMMARY

A. Section Includes:
   1. Phenolic-foam ducts and fittings **(Applicable For indoor ducts in this project)**

80.2 PERFORMANCE REQUIREMENTS

A. Thermal Performance: The thermal conductivity (λ) of the insulation materials shall not exceed. 0.146 Btu.in/hr.ft2.°F (0.021 W/mK) at 75 °F (24 °C) mean.

Minimum 90% closed cell core structure as tested to ISO 4590 in accordance with Clause 3.2.2 of ASTM 1126 Standard Specification for Rigid Cellular Phenolic Thermal Insulation requirements.

The installed insulation thickness shall satisfy the requirements of ANSI/ASHRAE/IESNA Standard 90.1 Standard for the minimum ductwork insulation thickness. Under no circumstance shall the installed thickness of insulation be less than the specified thickness of insulation. Should the insulation material be susceptible to compression when stretched around the ductwork during installation, a 25% compression factor shall be taken into account i.e. the installed thickness shall be assumed to be 75% (25% compression) of nominal thickness.

A. Duct Design: The design of nonmetal ductwork shall follow the same calculation principles and duct sizing methods as are used for rectangular ductwork constructed from galvanized sheet steel.

B. Static-Pressure Classes:
   a. Supply Ducts (Positive Pressure): max 4-inch wg (1000 Pa).
   b. Return Ducts (Negative Pressure): max 3-inch wg (750 Pa).

C. UL 181 Listing: Nonmetal ductwork shall be constructed to be UL Listed as a Class 1 air duct to Standard for Safety UL 181

D. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

80.3 SUBMITTALS

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

B. LEED Submittals:

1. Product Data for Prerequisite EQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1-2010, Section 5 - "Systems and Equipment."
2. Product Data for Prerequisite EA 2: Documentation indicating that duct systems complies with ASHRAE/IESNA 90.1-2010, Section 6.4.4 - "HVAC System Construction and Insulation."
3. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1-2010, Section 6.4.4.2.2 - "Duct Leakage Tests."
4. Duct-Cleaning Test Report for Prerequisite EQ 1: Documentation of work performed for compliance with ASHRAE 62.1-2010, Section 7.2.4 - "Ventilation System Start-Up."
5. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.

80.4 QUALITY ASSURANCE

A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2010, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

B. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2010, Section 6.4.4 - "HVAC System Construction and Insulation."

C. NFPA Compliance:

1. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
2. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

D. ISO 9001 and 14001 Compliance:

1. ISO 9001, "Quality management systems. Requirements"
2. ISO 14001 "Environmental Management Systems. Requirements"

PART 81 - PART 2 - PRODUCTS

81.1 PHENOLIC-FOAM DUCTS AND FITTINGS

A. Duct Panel: CFC/HCFC -free rigid phenolic-foam bonded on both sides with factory-applied 0.001 inch (0.025 mm) thick aluminum foil reinforced with fiberglass scrim.

1. Temperature Limits: -15°F to +185°F (-26°C to +85°C) inside ducts or ambient temperature surrounding ducts.
2. Maximum Thermal Conductivity: 0.146 Btu.in/ft².hr.ºF (0.021 W/mK) at 75°F (24°C) mean temperature.
3. Permeance of the external facing: 0.02 perm (1.15 ng/s·m2·Pa) maximum when tested according to ASTM E 96/E 96M, Procedure A.
4. Resistance to the spread of mold: Ductwork shall be UL 181 Listed and shall pass the Mold Growth and Humidity Test of UL 181 Standard for safety.
5. Required Markings: UL label and other markings required by UL 181 on each full sheet of duct panel.

B. Closure Materials:

1. V-Groove Sealant:
    a. For indoor applications, use sealant that has a VOC content of 250 g/l or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2. Pressure-Sensitive Tape: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-P," the manufacturer's name, and a date code.
    a. Tape: Aluminum foil tape imprinted with listing information.
    b. Minimum Tape Width: 2 1/2 inches (63 mm).

C. Fabrication:

1. Fabricate joints, seams, transitions, elbows, branch connections, access doors, and damage repairs according to manufacturer’s recommendations and guidelines
2. Fabricate 90-degree mitered elbows to include turning vanes.
3. Reinforcements: Comply with to manufacturer’s recommendations and guidelines

2.2 HANGERS AND SUPPORTS

A. Hangers and Supports: Galvanised steel.

B. Hangers and Supports Sizes: Comply with the maximum allowable load of SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5 "Hangers and Supports”, bearing in mind the light weight nature of non-metal ducts

2.3 SEISMIC-RESTRAINT DEVICE

A. Provide seismic restraints as necessary to meet the requirement of the authority having jurisdiction.

PART 82 - PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Ducts shall be installed by experienced contractors who have received appropriate training for the installation of non-metal ducts
B. Install ducts with fewest possible joints.
C. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
D. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
E. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers.
F. Protect duct interiors from the moisture, construction debris and dust, and other foreign materials. [Comply with SMACNA's "Duct Cleanliness for New Construction Guidelines"].
G. Install non-metal ducts and fittings to comply with manufacturer's recommendations and guidelines.
H. Prevent objectionable damage to the duct segments during transportation and storage

3.2 HANGER AND SUPPORT INSTALLATION

A. Install hangers and supports for non-metal ducts and fittings to comply with manufacturer's design guide.
B. Building Attachments: fasteners appropriate for construction materials to which hangers are being attached.
C. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials.

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:

1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
2. The air leakage class achievable shall be SMACNA Class 3
3. Conduct tests at static pressures not exceeding the maximum design operating pressure of system or section being tested. In any case, pressure must not exceed the maximum pressure rating to which the ductwork has been fabricated

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.
2. If required, test sections of non-metal duct system for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

3.4 DUCT CLEANING

A. If required, clean duct system(s) before testing, adjusting, and balancing.

B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Comply with Spec Division 23 Section "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

D. Mechanical Cleaning Methodology:

1. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
2. Use mechanical agitation suitable for non-metal ducts to dislodge debris adhered to interior duct surfaces without damaging integrity of ducts or duct accessories.
3. Clean non-metal duct with HEPA vacuuming equipment; do not permit duct to get wet. Replace/repair duct that is damaged, deteriorated, or delaminated.
4. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
5. Provide drainage and clean-up for wash-down procedures.
6. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents suitable for non-metal ducts if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

3.5 START UP

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

3.6 DUCT SCHEDULE

A. Indoor Ducts and Fittings:

1. Phenolic-Foam Rectangular Ducts and Fittings:
   a. Minimum Panel Thickness: 7/8 inch (22 mm),
   1 3/16 inch (30 mm)
   b. Aluminum Cladding (if required): Minimum 0.025 inch (0.635 mm) thick.

B. Outdoor Ducts and Fittings:

1. Phenolic-Foam Rectangular Ducts and Fittings:
   a. Minimum Panel Thickness: 1 3/16 inch (30 mm)
   b. Mechanical & weather protection is required for all non-metal ductwork installed outdoor; provide products by one of the following (all applied in accordance with manufacturer recommendations and project specification requirements):
   - Aluminum cladding or aluminum–zinc alloy coated steel sheet, minimum 0.032 inch (0.813 mm) thick;
   - heavy–duty self–adhesive laminate (e.g. Venture Clad by Venture Tape or equivalent);
   - synthetic elastomeric jacketing systems;
   - reinforcing glass / synthetic cloth embedded between two coats of appropriate coating;
   - UV resistant glass reinforced polyester / epoxy (GRP / GRE) cladding system.

   c. All coupling points / joints must be fully weatherproofed.

XXXI. FRESH AIR HANDLING UNIT

PART 83 - GENERAL

83.1 SUMMARY

Section Includes:

- Modular double skin fresh air handling units with heat recovery wheel.
- Modular double skin fresh air handling units without heat recovery wheel.

83.2 PERFORMANCE REQUIREMENTS

Delegated Design: Design vibration isolation and seismic-restraint details, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

Structural Performance: Casing panels shall be self-supporting and mechanical strength shall be of class D1 for mechanical deflection as per EN 1886 standards.

Seismic Performance: Contractor should ensure the unit assembly shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

- The term "withstand" means "the unit assembly will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

83.3 ARRANGEMENT

The air handling unit shall be a horizontal draw-thru unit containing fan section, chilled water-cooling coil section, Enthalpy Heat recovery section, sensible heat wheel, 2" thick washable synthetic air filter, 600 mm long high efficiency bag filter, access panel sections and condensate drain pans. Drain pans shall extend over the entire coil length and shall be of stainless steel SS304 construction for corrosion resistance and shall be insulated.

Fresh Air Unit installed at roof direct to sun shall be with factory supplied protective canopy.

All Construction support elements of the air handling shall be insulated and provided with proper thermal bridges of TB2 standard as per EN 1886 standards (thermal break profile) all around the unit corners, to prevent unit sweating and condensation at the outer skin of the unit.

83.4 SUBMITTALS

Product Data: For each air-handling unit indicated.

- Unit dimensions and weight.
- Cabinet material, metal thickness, finishes, insulation, and accessories.
- Fans:

n. Certified fan-performance curves with system operating conditions indicated.

o. Certified fan-sound power ratings.

p. Fan construction and accessories.

q. Motor ratings, electrical characteristics, and motor accessories.

- Certified coil-performance ratings with system operating conditions indicated.
- Dampers, including housings, linkages, and operators.
- Filters with performance characteristics.

Compliance with ASHRAE 62.1 requirements:

- Contractor shall comply with Building Mechanical System Requirements to protect the quality of air drawn into buildings for ventilation and to ensure minimum delivery of outdoor fresh air such as:

- Separation distances between outdoor air intakes and any exhausts or discharge points comply with ASHRAE 62.1.2007 of local code whichever is more stringent.
- All exhausts are located outside of the defined public realm or as defined by local code, whichever is more stringent.
- Contractor shall submit As-Built Mechanical System drawings marked – up to clearly show distances between air intake points and exhaust air or other discharge points and the distances from the air exhaust points to any defined public realm areas.

Delegated-Design Submittal: For vibration isolation and seismic restraints indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

- Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
- Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.

Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

- Mechanical-room layout and relationships between components and adjacent structural and mechanical elements.
- Support location, type, and weight.
- Field measurements.

Seismic Qualification Certificates: For air-handling units, accessories, and components, from manufacturer.

- Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
- Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
- Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

Source quality-control reports.

Field quality-control reports.

Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

83.5 QUALITY ASSURANCE

Electrical Components, Devices, and Accessories: Listed and labeled as defined in NEC and UL standards 1996 by a qualified testing agency, and marked for intended location and application.

NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components for flame spread and smoke generation.

EUROVENT Certification: Air-handling units and their components shall be factory tested according to EN 1886 based on measurements carrier out on a model box for Central-Station Air-Handling Units and performance shall be listed as mentioned below:

- Mechanical Strength Class D1
- Casing Air Leakage Class L1
- Filter By-Pass Leakage Class F8
- Thermal Transmittance Class T2
- Thermal Bridging Class TB2
- Acoustic insulation

HZ	125	250	500	1000	2000	4000	8000

dB	9.2	10. 5	12. 4	13.5	20.4	34.7	42

ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2007, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

AMCA & DIN Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal and DIN standards.

ASHRAE/IESNA 90.1-2010 Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2010, Section 6 - "Heating, Ventilating, and Air-Conditioning."

ASHRAE compliance 52-76: Filter should comply with ASHRAE 52-76 standard or EUROVENT standard 5/6.

ISO 9001:2000: Units shall be manufactured in a ISO 9001:2000 certified factory for quality processes.

ASTM B117: Casing shall withstand the 500 hours of salt spray exceeding the ASTM B117 requirement.

COORDINATION

Coordinate sizes and locations of concrete bases with actual equipment provided.

Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

EXTRA MATERIALS

Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

- Filters: One set for each air-handling unit.
- Gaskets: One set for each access door.
- Fan Belts: One set for each air-handling unit fan.

PART 84 - PRODUCTS

84.1 MANUFACTURERS

Manufacturers: Subject to compliance with requirements, provide from the list of approved manufacturers:

84.2 UNIT CASINGS AND INSULATION

Construction:

- Each unit shall be designed and constructed for ease of handling and replacement or addition of sections.
- Each section shall be of the same construction type and present a smooth internal appearance to ensure even airflow through the components and prevent dirt build up.
- The cross section of the unit should be based on the plant room configuration proposed, taking full account of maintenance access requirements.
- Each section of AHU shall be provided with interior lighting. A micro switch shall be provided in each door/panel to operate the light, when the door/panel is opened.
- The unit shall be of framed construction for strength and rigidity. Frames shall be structurally rigid, fully welded and hermetically sealed at ends and provided with Galvanized Sheet Steel channel bases under all units. These shall be a minimum of 62 mm high, the actual height being individually calculated for each unit to ensure structural integrity during lifting and moving.
- All individual components and sections shall be assembled using proprietary and suitable fastening techniques. Locking devices shall be used with all fastenings that are subject to vibration.
- Casing shall completely enclose the coils, fans, filter sections and return air plenum.
- Panels shall be removable for access and complete with access door for inspection of the fan, motor, coil and filter.
- Galvanized steel bolts, screws and washers shall be used for the assembly of the units.
- Fabricate structural frame with members rigidly braced to hold all parts in line and to prevent change in shape when operating.
- Unless otherwise specified, structural frame of welded construction shall be painted with highly durable heat hardened polyester based powder paint RAL7035 with 50 microns film thickness.
- Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2010.
- Frame members shall be mechanically fixed and sealed with fire retardant gaskets to give the necessary structural strength and air leakage integrity.
- All modular panel metal surfaces must be properly treated with a weather and scratch-resistant coating on both sides and painted with base colour (RAL-7035) in the manufacturer's works as standard provision.
- The casing panels shall be of rigid double-skinned modular construction, corrosion resistant and structurally adequately to be free from distortion and drumming in operation.
- They shall be insulated with polyurethane foam of 40 kg/m3 density with fire retardant according to DIN 4102 class B and with pre coated/powder coated 0.8 mm galvanized steel inside and outside casing.

- The insulation shall be injected between the outer and inner casing. Insulation shall have a thermal conductivity no greater than 19 W/mC. Thermal insulation shall be securely fixed to all sections handling cooled air and, where appropriate, a vapour barrier shall be provided.
- Particular care shall be taken to ensure surface protection of internal insulation in areas where free moisture may be present and to avoid damage in sections having walk-in access.
- Thermal insulation shall be selected and applied to prevent surface condensation at design conditions and to maximize noise attenuation. Insulation for panels and all structural or reinforced members shall be 60 mm thick.
- Surface condensation shall not occur even when the AHUs are in operation or are exposed to outdoor ambient temperature and humid conditions. The complete unit design including framework, panels, access door handles, and hinges shall be designed such that there shall be no thermal bridge and thermal bridging factor kb 0.62 conformed to Eurovent EN1886 class TB2.
- The design of the unit shall be free from cold bridges. There shall be no direct metallic contact between the inside and the outside of the cabinets.
- Panel construction shall provide minimum casing air leakage of Class L1 as per EUROVENT standard EN1886.
- Lifting lugs shall be provided such that each unit shall be capable of being lifted as both a complete assembly, and as sub sections to facilitate handling and installation.
- Hinged access doors with handles should be opened with a special key and doors air seals shall be provided to facilitate access to be made to upstream and downstream faces and all internal parts such as the cooling coils, drain pans, filter, fan and bearings etc.
- Floors at all accessible sections shall be designed for a 5 kPa loading.
- Doors/access panels shall be 480mm (minimum width) and at least 1500 mm high and shall be secured with a minimum number of fastenings consistent with effective EPDM rubber air sealing.
- Air handling unit panels shall be protected by galvanizing for anti-corrosion protection or a similar finish in the internal surfaces of the units liable to be affected by any moisture.

Inspection and Access Panels and Access Doors:

- Panel and Door Fabrication: Formed and reinforced, single- or double-wall and insulated panels of same materials and thicknesses as casing.
- Inspection and Access Panels:
- Locations and Applications:

  r. Fan Section: Doors.

  s. Access Section: Doors.

  t. Coil Section: Inspection and access panel.

  u. Filter Section: Inspection and access panels large enough to allow periodic removal and installation of filters.

  v. Mixing Section: Doors.

- Service Light: 60-W vapor proof fixture with switched junction box located inside adjacent to door.

Condensate Drain Pans:

- Fabricated with single skin one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and to direct water toward drain connection.

- Constructed of SS304 Stainless steel; Complete with copper or galvanized steel connector for connection of condensate drain pipes and able to connect on both sides with drain pipes of adequate size.
- Extend pan over the full width and depth of the coil sections and the coil headers; and of sufficient clearance from the coil header to facilitate maintenance and cleaning.
- Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.

- Seismic Fabrication Requirements: Fabricate mounting base and attachment to air-handling unit sections, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" when air-handling unit frame is anchored to building structure.

84.3 FAN, DRIVE, AND MOTOR SECTION

Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower in compliance to DIN ISO standard 1940 with Grade 4.

- Shafts: Made up of C45 carbon steel bar with yellow protective paint designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment. Shaft diameters are selected to achieve a safety factor for critical speed ≥ 1.25 higher than the maximum operating speed.

Centrifugal Fan Housings: Formed- and reinforced-steel panels to form curved scroll housings with shaped cut off and spun-metal inlet bell.

- Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.
- Horizontal-Flanged, Split Housing: Bolted construction.
- Housing for Supply Fan: Attach housing to fan-section casing with metal-edged flexible duct connector.
- Flexible Connector: Factory fabricated with a fabric strip 146 mm wide attached to 2 strips of 70-mm- wide, 0.7-mm- thick, galvanized-steel sheet; select metal compatible with casing.

Backward Airfoil Curved: Inclined, Centrifugal Fan Wheels, Double-Inlet-Double-Width construction with curved inlet flange, side plate, galvanized steel backward airfoil blades treated with polyester powder coat RAL 7030 joined by using Pittsburgh lock forming system to flange and side plate to prevent any oxidation from the welding spot.

Fan Shaft Bearings:

- Pre lubricated and Sealed, Ball Bearings: Self-aligning, pillow-block type with a rated life of 200,000 L50 hours according to DIN ISO 281 section 1.

Belt Drives: Factory mounted, with adjustable alignment and belt tensioning, and with 1.5 service factor based on fan motor.

- Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
- Motor Pulleys: Adjustable pitch for use with 5 hp motors and smaller; fixed pitch for use with motors larger than 5hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.
- Belts: Oil resistant, non-sparking, and non-static; in matched sets for multiple-belt drives.

Discharge Dampers: Heavy-duty steel assembly with channel frame and sealed ball bearings, and opposed blades constructed of two plates formed around and welded to shaft, with blades linked out of air stream to single control lever.

Internal Vibration Isolation and Seismic Control: Fans shall be factory mounted with manufacturer's standard restrained vibration isolation mounting devices having a minimum static deflection of 50 mm to achieve critical vibration isolation efficiency E95 up to E99.9.

Motor: Comply with IEC 34-1 designation; temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

- Enclosure Type: Totally enclosed, fan cooled.
- IEC Premium (TM) efficient motors
- Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven loads will not require motor to operate in service factor range above 1.0. Normally closed thermostat type overload protection shall be provided.
- Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.
- Motor shall have Class F insulation and Class B for temperature rise and should be able to work up to 50 C operating temperature.

84.4 COIL SECTION

General Requirements for Coil Section:

- Coils fabricated and tested in accordance with ASHRAE/ANSI 15 Safety Code for Mechanical Refrigeration (latest edition).
- Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
- For multi zone units, provide air deflectors and air baffles to balance airflow across coils.
- Coils shall not act as structural component of unit.
- Cooling coils shall be made of copper tubes and aluminium fins. Copper tube shall not be less than 0.4mm thick and 12.7mm in diameter.
- Cooling coils shall be designed to operate with chilled water. Maximum water velocity shall be 2.5m/s
- Where water velocities of less than 0.60 m/s are encountered, a method of turbulation shall be provided.
- The coil size shall be designed at a maximum operating air velocity of 2.5 m/s. The coils shall be designed to operate at 1600 kPa working pressure and 93°C temperature.
- The protection against corrosion shall be designed for polluted and aggressive atmosphere.
- Cooling coils shall be designed for air supply conditions and related RH as specified in the Schedule of equipment.
- The resistance to air flow through a cooler battery shall not exceed 250 Pa for AHUs taking into account of wet air condition and the face velocity shall not exceed 2.5 m/s
- Moisture carry over from the coil shall not be permitted.
- Factory test water coils at 1600 kPa for low pressure system as specified for system operating pressure less than 1035 kPa Factory test water coil at 2100 kPa for system operation up to 1600 kPa

- Nameplates: Securely attach nameplate on each coil showing manufacturer's name, serial and model number.
- Seamless de-oxidized 12.7 mm outside diameter copper tubes for AHUs and PACs with minimum 27 gauge wall thickness brazed copper return bends shall be used.
- Aluminium plate fins mechanically bonded to the tubes or aluminium helical fins mechanically bonded to the tubes shall be used.
- Minimum thickness of fins shall be 0.12mm.
- Unless otherwise specified, headers shall be heavy gauge copper tube with supply and return connections, drain and vent on each header.
- Coil casing shall be flanged with minimum 18 gauge galvanized steel. Top and bottom casing flanges shall be formed into a reinforced galvanized steel channel
- Coil having effective height greater than 1.6 m shall be horizontally divided into two sections and an intermediate drain pan with two drop tubes to the main drain pan shall be provided.
- Coils shall be designed with no bypass between coil sections (for AHUs with 1 m to 1.8 m tube length shall be provided with one centre tube support. For longer coils up to 3 m tube length, it shall be provided with two intermediate supports and over 3 m long tubes shall be provided with three intermediate supports
- For AHUs fin spacing shall not be more than 12 fins per 25.4 mm of tube. Coil shall be of 6 rows deep minimum. However, FCU coil shall be of 4rows deep minimum.
- Unless otherwise specified, water velocity shall be minimum 0.6 m/s and maximum 2.44 m/s throughout the tube length. Chilled water coils shall be selected so that water flow remains turbulent at 40 %of the design flow rate.
- Seismic Fabrication Requirements: Fabricate coil section, internal mounting frame and attachment to coils, and other coil section components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" when coil-mounting frame and air-handling-unit mounting frame are anchored to building structure.

84.5 AIR FILTRATION SECTION

General Requirements for Air Filtration Section:

- Comply with NFPA 90A.
- Provide minimum arrestance according to ASHRAE 52.1 or equivalent EN779, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2 or equivalent EN779.
- Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.

Extended-Surface, Disposable Panel Filters:

- Factory-fabricated, dry, extended-surface type.
- Thickness: 50 mm.
- Arrestance (EN779): G4
- Merv (ASHRAE 52.2): 5.
- Media: Flat or pleated foam with synthetic media which is cleanable and washable type.
- Media-Grid Frame: Galvanized steel.

- Mounting Frames: Galvanized steel with gaskets and fasteners and should be sealed for a minimal air leak Class F8 according to EN 1886

Extended-Surface, non-supported-Media Bag Filters:

- Factory-fabricated, dry, extended-surface, self-supporting type.
- Thickness: 500 mm.
- Arrestance (EN779): F8
- Merv (ASHRAE 52.2): 14.
- Media: Synthetic media which perform well up to 100% relative humidity and in high airflow and heavy dust loading conditions.
- Filter-Media Frame: Galvanized steel.
- Mounting Frames: Galvanized steel with gaskets and fasteners and should be sealed for a minimal air leak Class F8 according to EN 1886

Filter Guage:

- 50-mm- diameter, diaphragm-actuated dial in metal case.
- Vent valves.
- Black figures on white background.
- Front recalibration adjustment.
- 2 percent of full-scale accuracy.
- Range: 0 to 750 Pa.
- Accessories: Static-pressure tips with integral compression fittings, 6-m, plastic tubing, and 2- or 3-way vent valves.

84.6 DAMPERS

General Requirements for Dampers: Standard class IV air leakage, 0.5% leakage rate at 100 Pascal per square meter damper area, according to UL555S.

Damper Operators: Comply with requirements in Division 23 Section "Instrumentation and Control for HVAC."

- Spring-Return Motors: Size for running and breakaway torque of 16.9 N x m.

Outdoor- and Return-Air Dampers: Low-leakage, single-skin, laminar type galvanized steel blades in opposed-blade arrangement with shaft of 12 mm diameter seated on a non-corrosive nylon bushing for less resistance. Leakage rate shall not exceed 0.5% leakage rate at 100 Pascal ΔP per square meter damper area.

84.7 AIR-TO-AIR ENERGY RECOVERY

HEAT RECOVERY WHEELS

- Manufacturers: Subject to compliance with requirements, provide from the list of Approved Manufacturer’s.
- The constructions of the heat recovery wheel shall be as under:
- **The substrate:**
- The substrate or wheel matrix should be only of pure aluminium foil so as to allow:

  a) Quick and efficient uptake of thermal energy.

  b) Sufficient mass for optimum heat transfer

c) Maximum sensible heat recovery at a relatively low rotational speed of 20 to 25 rpm.

- Each fresh air handling units shall have one enthalpy heat recovery wheel each.
- **Heat Wheel Testing:**
- A minimum quantity of 10-15% of the heat wheel quantity will be tested at the manufacturer's factory.
- The manufacturer shall have in their own test laboratory, the facility to test the performance of the heat recovery wheels, as per design conditions.
- The test laboratory shall be certified by a reputed independent agency,
- During the test, the manufacturer shall demonstrate the performance of the heat wheel for at least 1 quantity, for various weather conditions, by simulating these conditions in their test laboratory.
- **Heat Recovery Wheel Constructions:**
- Non-metallic substrates made from paper, plastic, synthetic or glass fibre media, will therefore, not be acceptable.
- The substrate shall not be made from any material, which is combustible or supports combustion.
- The Heat Wheel shall have been successfully tested to Confirm ZERO FLAME SPREAD, as per NFPA 90A. **Higher flame spread percentages shall not be acceptable.**
- The flame spread shall be done as per NFPA 90A requirements.
- **The Desiccant:**
- The desiccant should be water molecule selective and non-migratory.
- The desiccant should be molecular sieve 3Å, so as to keep the cross contamination to absolute minimum and also ensure the exclusion of contaminants from the air streams, while transferring the water vapour molecules.
- The desiccant, of sufficient mass, should be coated with non-masking porous binder adhesive on the aluminium substrate so as to allow quick and easy uptake and release of water vapour. A matrix with desiccants impregnated in non-metallic substrates, such as synthetic fibre, glass fibre, etc. will not be accepted.
- The rotor/wheel matrix shall have **equal** sensible and latent recovery in the range of 80–85% Total Effectiveness.
- The weight of desiccant coating and the mass of aluminium foil shall be in a ratio so as to ensure equal recovery of both sensible and latent heat over the operating range.

  Accordingly, a rotor matrix, which has an etched or oxidized surface to make a desiccant on a metal foil and results in insufficient latent recovery and hence unequal recovery, or a rotor matrix made from desiccant integrated in a synthetic fibre matrix, which result in insufficient sensible recovery, high rotation speed, and unequal recovery, will not be accepted.
- **Rotor:**
- The rotor shall be made of alternate flat and corrugated aluminium foil of uniform width.

- The rotor honeycomb matrix foil should be so wound and adhered as to make a structurally very strong and rigid media which shall not get cracked, deformed etc. due to change of temperature or humidity.
- The rotor having a diameter up to 2800 mm shall have spokes to reinforce the matrix. From 2000 mm diameter upwards, the option of a special wing structure, to prevent the rotors from wobbling or deforming due to the successive pressure differentials, will be available.
- Sectioned wheels, with pie segments, capable of being assembled in the field, shall be available as an option, above 2000 mm in diameter.
- The surface of the wheel/rotor should be highly polished to ensure that the vertical run out does not exceed + 1 mm for every 1 metre diameter, thereby ensuring, negligible leakage, if labyrinth non-contact seals are provided, and minimal drag, if contact wiper seals are provided.
- The radial run out also shall not exceed + 1 mm for every 1 meter diameter, thereby minimising the leakage/drag on the radial seals, and minimise the fluctuation in the tension of the drive belt.
- The number of wraps (of alternative corrugated and flat foil) for every inch of rotor radii shall be very consistent so as to ensure uniform air flow and performance over the entire face in the air stream. Flute height and pitch will be consistent to a very tight tolerance to ensure uniform pressure drop and uniform airflows across the rotor face.
- The rotor shall be a non-clogging aluminium media, having a multitude of narrow aluminium foil channels, thus ensuring a laminar flow, and will **allow particles up to 800 microns** to pass through it.
- With optimum heat and mass through matrix formed by desiccant, of sufficient mass, coated on an aluminium foil, the rotor should rotate at lower than 20 to 25 RPM, thereby also ensuring long life of belts and reduced wear and tear of seals. The media shall be cleanable with compressed air, or low-pressure steam or light detergent, without degrading the latent recovery.
- **The Cassette / casing**
- The recovery wheel cassette/casing shall be manufactured from tubular structure to provide a self-supporting rigid structure, complete with access panels, purge sector, rotor, bearings, seals, drive mechanism complete with belt.
- The rotor/wheel should have a field adjustable purge mechanism to provide definite separation of airflow minimizing the carryover of bacteria, dust and other pollutants, from the exhaust air to the supply air. It shall be possible, with proper adjustment, to **limit cross contamination to less than 0.04%** of that of the exhaust air concentration.
- The face and radial seals shall be **four (4) pass non-contact** labyrinth seals for effective sealing between the two air streams, and also for a minimum wear and tear ensuring infinite life of the seals.

Heat Wheel Operations:

- The selection of the heat wheel shall be done in such a way as to have a minimum total effectiveness of at least 85 – 90% (85-90% Sensible and 85-90% latent effectiveness)
- The minimum thickness of the Heat Recovery wheel shall be 270 mm.

- The heat wheel shall be selected to operate at a maximum face velocity of 3.75 to 4.0 m/s.
- Higher face velocities are not acceptable.
- **Heat Wheel Testing:**
- The selection of the heat wheel shall be done in such a way as to have a minimum total effectiveness of at least 85 – 90% (85-90% Sensible and 85-90% latent effectiveness)
- The minimum thickness of the Heat Recovery wheel shall be 270 mm.
- The heat wheel shall be selected to operate at a maximum face velocity in the range of of 3.0 to 3.5 m/s.
- Higher face velocities are not acceptable.

HEAT PIPE DEHUMIDIFICATION COILS

- Manufacturers: Subject to compliance with requirements, provide from the list of Approved Manufacturer's.
- A minimum of 100mm gap should be allowed between the leaving face of the cooling coil and the entering face of the heat pipe reheat section. This gap will permit the installation of sensors or other instrumentation to monitor the condition of the air after the cooling coil.
- The external fins shall be of aluminium with a minimum thickness of 0.15mm. Fins shall be of the continuous plate type and louvered type. Tubes shall be of refrigeration standard seamless copper C106 for heat exchanger use. Tube diameter shall be 12mm with a grooved inner surface and minimum root thickness of the tube shall be 0.35mm. Casings shall be from galvanized sheet steel with a minimum thickness of 1.6mm. The casing shall incorporate tube plates and top and bottom plates around both the precool and reheat heat pipe blocks.
- The working fluid shall be refrigerant type classified as **ASHRAE safety group A1**. The refrigerant shall be R134A. The heat pipe circuits shall be factory charged and hermetically sealed with the calculated weight of refrigerant.
- There shall be a multitude of loops in the height of the heat pipe and each loop shall be individually charged. Heat pipes with header assemblies containing a single circuit are not suitable as a single leak will render the entire heat pipe inoperative
- Heat pipes shall be designed to comply with the specified conditions when subject to the air volumes given in the specification.
- Heat pipe performance shall be independently type tested and certified in line with the requirements of **British StandardsBS 5141 pt1** or European Standards **EN 305 & 306** or **American Standards ARI 410** for testing and rating of heat exchangers.
- The heat pipe should strictly have a **third party independent type test report conducted by Eurovent certified laboratories** like CETIAT (FRANCE) or BSRIA (U.K.).
- The heat pipe manufacturer shall have minimum 10years experience in manufacturing of heat pipes and must have heat pipes commissioned for a minimum period of 5 years in the Middle East market.

SOURCE QUALITY CONTROL

Fan Sound-Power Level Ratings: Comply with AMCA 300 & 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.

Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 200, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."

Water Coils: Factory tested to 2100 KPa submerged under water.

Factory test AHU's, before shipping, according to Eurovent EN1886 to verify the fan performance.

- The tests shall be witnessed by the Engineer at the place where AHU are being tested. Notify Engineer 30 days in advance of testing. Contractor to bear all costs for testing, traveling, boarding/lodging for witnessing the tests.
- Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

PART 85 - EXECUTION

85.1 EXAMINATION

Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.

Examine roughing-in for, hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.

Proceed with installation only after unsatisfactory conditions have been corrected.

85.2 INSTALLATION

Equipment Mounting: Install air-handling units on concrete bases using restrained spring isolators. Secure units to anchor bolts installed in concrete bases.

- Minimum Deflection: 25 mm.

Suspended Units: Suspend and brace units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

Arrange installation of units to provide access space around air-handling units for service and maintenance.

Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.

Install filter-gauge, static-pressure taps upstream and downstream of filters. Mount filter gauges on outside of filter housing in accessible position. Provide filter gauges on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

85.3 CONNECTIONS

Comply with requirements for piping specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

Install piping adjacent to air-handling unit to allow service and maintenance.

Connect piping to air-handling units mounted on vibration isolators with flexible connectors.

Connect condensate drain pans using DN 32 PVC pipes Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

Hot- and Chilled-Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Install shutoff valve and union or flange at each coil supply connection. Install shutoff valve and auto balancing valve and union or flange at each coil return connection.

Connect duct to air-handling units with flexible connections. Comply with requirements in Division 23 Section "Air Duct Accessories."

85.4 FIELD QUALITY CONTROL

Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

Perform tests and inspections.

- Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Tests and Inspections:

- Leak Test: After installation, fill water coils with water, and test coils and connections for leaks.
- Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

Prepare test and inspection reports.

85.5 STARTUP SERVICE

Engage a factory-authorized service representative to perform startup service.

- Complete installation and startup checks according to manufacturer's written instructions.
- Verify that shipping, blocking, and bracing are removed.
- Verify that unit is secure on mountings and supporting devices and that connection to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
- Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
- Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
- Verify that zone dampers fully open and close for each zone.
- Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
- Comb coil fins for parallel orientation.
- Verify that proper thermal-overload protection is installed for electric coils.
- Install new, clean filters.
- Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

Starting procedures for air-handling units include the following:

- Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm. Replace fan and motor pulleys as required to achieve design conditions.
- Measure and record motor electrical values for voltage and amperage.
- Manually operate dampers from fully closed to fully open position and record fan performance.

85.6 ADJUSTING

Adjust damper linkages for proper damper operation.

Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

85.7 CLEANING

After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

85.8 DEMONSTRATION

Engage a factory-authorized service representative to train. Owner’s maintenance personnel to adjust, operate, and maintain air-handling units

XXXII. GROUND LOOP HEAT PUMP SYSTEMS

PART 86 - PART 1 GENERAL

86.1 SCOPE

This guide specification covers the Design and Installation requirements for Ground Source Closed-Loop Heat Pump systems.

86.2 REFERENCED CODES AND STANDARDS

The publications listed below form a part of this specification to the extent referenced.

ANSI/CSA/IGSHPA C448-16	Design and installation of ground source heat pump systems for commercial and residential buildings
ANSI/NSF Standard 60	Drinking Water Treatment Chemicals – Health Effects.
ANSI/NSF Standard 6	Drinking Water Treatment Chemicals – Health Effects.
ASME/ANSI B16.40	Manually Operated Thermoplastic Gas Shutoff Valves in Gas Distribution Systems.
ASTM C177	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus.
ASTM C1147	Standard Practice for Short Term Tensile Weld Strength of Chemical-Resistant Thermoplastics.
ASTM D2513	Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings.
ASTM D2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings.
ASTM D2683	Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing www.astm.org
ASTM D2774	Standard Practice for Underground Installation of Thermoplastic Pressure Piping.
ASTM D2837	Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
ASTM D3035	Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM D5334	Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure.
ASTM F645	Standard Guide for Selection, Design, and Installation of Thermoplastic Water-Pressure Piping Systems.
ASTM F713	Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter.
ASTM F876	Standard Specification for Cross-linked Polyethylene (PEX) Tubing.
ASTM F897	Standard Test Method for Measuring Fretting Corrosion of Osteosynthesis Plates and Screws.

ASTM F877	Standard Specification for Cross-linked Polyethylene (PEX) Hot-and Cold-Water Distribution Systems.
ASTM F1055	Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing
ASTM F1807	Standard Specification for Metal Insert Fittings Utilizing Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing.
ASTM F1960	Standard Specification for Cold Expansion Fittings with PEX Reinforcing Rings for Use with Cross-linked Polyethylene (PEX) Tubing.
ASTM F2080	Standard Specification for Cold Expansion Fittings with Metal Compression-Sleeves for Cross-linked Polyethylene (PEX) Pipe and SDR9 Polyethylene of Raised Temperature (PE-RT) Pipe.
ASTM 2159	Standard Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing.
ASTM F2164	Standard Practice for Field Leak Testing of Polyethylene (PE) and Cross-linked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure.
ASTM F2620	Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings.
AWWA C901	Polyethylene (PE) Pressure Pipe and Tubing, 3/4 in. (19 mm) through 3 in. (51mm) for Water Service.
CSA B137.1	Polyethylene Pipe, Tubing, and Fittings for Cold Water Pressure Services.
CSA B137.4	Polyethylene Piping Systems for Gas Services.
NSF/ANSI 358-1	Polyethylene Pipe and Fittings for Water-Based Ground-Source Geothermal Heat Pumps Systems.
NSF/ANSI 358-3	Cross-linked Polyethylene (PEX) Pipe and Fittings for Water-Based Ground-Source (Geothermal) Heat Pump Systems.
IGSHPA 21010	(1991) Grouting Procedures for Ground-Source Heat Pump Systems
IGSHPA 21015	(2000) Grouting for Vertical GHP Systems
IGSHPA 21020	(1988) Closed-Loop/Ground-Source Heat Pump System/Installation Guide
IGSHPA 21035	(2017) Design and Installation Standards
IGSHPA 21060	(1989) Soil and Rock Classification Field Manual

86.3 SYSTEM DESCRIPTION

Design and install: GROUND-LOOP HEAT PUMP SYSTEM DESIGN, CALCULATIONS, DETAIL DRAWINGS, SOIL THERMAL CONDUCTIVITY TESTING, and SYSTEM DESIGNER.

Design and provide new ground-loop heat pump systems complete and ready for operation. Systems shall include heat pumps, system equipment, piping, pumps, electrical equipment, controls, wells, and ground heat exchanger / condenser.

Design and installation of ground-loop heat pump systems including equipment, materials, installation, workmanship, fabrication, assembly, erection, examination, inspection, and testing shall be in accordance with ASME B31.9, ASME B31.5, ASHRAE FUN SI ASHRAE FUN IP, IGSHPA 21010, IGSHPA 21015, IGSHPA 21020, IGSHPA 21035, IGSHPA 21060, ASHRAE Item 90376, ISO 13256-2, ISO 13256-1 and ISO 13256-2 as supplemented and modified by this section. Provide ground coupled condenser loop piping by the requirements of this section.

86.4 GROUND-LOOP HEAT PUMP SYSTEM DESIGN

Design ground-loop heat pump systems in accordance with the required and advisory provisions of ASHRAE Item 90376, IGSHPA 21020 and IGSHPA 21035 except as modified herein. Provide calculations. Each system shall include materials, accessories, and equipment inside and outside the building to provide each system complete and ready for use. Design and provide each system to give full consideration to optimum well spacing and location, piping, electrical equipment, pumps, ground heat exchanger, and other construction and equipment in accordance with detailed working drawings to be submitted for approval. Locate ground-loop wells in a consistent pattern that would give the proper spacing between wells and the optimum performance. Provide well and piping system layout drawings.

86.5 CALCULATIONS

Methodology

Calculations shall be submitted as part of the design documentation. Provide calculations to determine the system design of the ground-loop heat pump system. Provide calculations for the HVAC loads and load profiles. Calculations shall include computer aided design programs that include the effects of thermal interaction between adjacent boreholes.

Calculations shall include submission of the software name and version, and design parameters. Design parameters shall include but not limited to soil conditions, ground water level, soil heat transfer coefficients, heat transfer coefficient for grout materials, etc. Heat transfer and other calculations shall be prepared by the System Designer using computer software specifically intended for ground-loop heat pump systems. The design shall be based on calculations that will provide the most life cycle cost effective ground-loop heat pump system using an expected life of 25 years and shall be sized based upon the loads shown on the drawings. Life cycle cost analysis shall be performed using the current discount rates, factors, and energy cost rates.

Design

The diameter, length, flow, velocity, friction loss, number and type fittings, total friction loss, and the maximum expected expansion and contraction of the pipe shall be indicated in the program output. An accompanying schematic drawing showing reference points used in the calculations shall be included with the calculations. The entering water temperature to the heat pumps under peak heating load design shall be 10 degrees C. Adjacent wells/system will not be spaced closer than 4 m.

86.6 DETAIL DRAWINGS

Prepare and provide A1 size detail working drawings showing the ground-loop heat pump system, layout, assembly and installation details, electrical connection diagrams and wiring diagrams, installation and details of pumps, distribution manifolds, heat pumps, piping, and well field layout. Show well grouting details in accordance to IGSHPA 21010 and IGSHPA 21015. Show data essential for proper installation of each system. Show details, plan view, elevations, and sections of the systems supply and piping. Drawings shall be scaled, show the North arrow, show the graphic scales, equipment schedules, legends, abbreviation definitions, notes, symbol lists, and any key plans.

Equipment schedules shall show the pump motor horsepower and power consumption. Show piping schematic of systems supply, devices, valves, pipe, and fittings. Show the well field arrangement. Show point to point Electrical Wiring Diagrams. The design and drawings shall show the piping lay out, piping sizes to transfer the heat required, including any boring, trenching, installation of piping, and connection to the piping in applicable HVAC System. Drawings shall include any information required to demonstrate that the system has been coordinated and will properly function within the HVAC system and shall show equipment relationship to other parts of the work, including clearances required for operation and maintenance and the test point locations where the ground-loop heat pump system will be monitored during testing. Submit drawings signed by a registered professional engineer.

System Diagrams

After completion, but before final acceptance, submit System diagrams that show the layout of equipment, piping, and circulation pumps, and typed condensed operation manuals explaining preventative maintenance procedures, methods of checking the system for normal, safe operation, and procedures for safely starting and stopping the system shall be framed under glass or laminated plastic. After approval, these items shall be posted where directed by the Contracting Officer. System diagrams may be submitted with operation and maintenance manuals.

86.7 SOIL THERMAL CONDUCTIVITY TESTING

Also known as In-situ Thermal response test, these tests shall be conducted in accordance with the procedures outlined in ASHRAE Item 90376 and Part 3.0 herein. The designer shall consider performing soil thermal conductivity testing at various locations at the project site. Due to possible variance in soil properties and ground water, it is advisable to perform multiple location testing. Test period duration = 72 hours.

86.8 SYSTEM DESIGNER

The ground-loop heat pump system(s) shall be designed by an individual who is a registered professional engineer / Certified Geo-Exchange Designer and is regularly engaged in the design of the type and capacity of system(s) specified in this project for the immediate three years prior to the submittal of the System Designer's Statement of Qualifications. Certification as a certified Geo-Exchange Designer shall be kept up to date and maintained with the Association of Energy Engineers. The System Designer's Statement of Qualifications shall include design experience in ground-loop heat pump systems, geothermal heat pump design, data identifying the location, ground-loop heat pump system type, and capacity of at least three systems designed by the proposed System Designer during that period. The Contractor shall furnish documentation from the owner of each of these three systems verifying that each system has performed in the manner intended for the 6 months prior to submission of the Statement of Qualifications.

86.9 GROUND SOURCE HEAT PUMP INSTALLER

Work specified in this section shall be performed by accredited ground source heat pump (GSHP) installers. The GSHP installer shall be an "Accredited Installer." Accreditation as an Accredited Installer shall be kept up to date and maintained with the International Ground Source Heat Pump Association (IGSHPA). The Accredited Installer shall be engaged in the installation of the type and capacity of the system(s) specified in this project for the immediate three years prior to the submittal of the GSHP installer's Statement of Qualifications. The GSHP installer's Statement of Qualifications shall include a copy of IGSHPA Installer Certification and data identifying the location, GSHP system type, and capacity of at least three systems installed under the guidance of the proposed GSHP Installer during that period. The Contractor shall furnish documentation from the owner of these three GSHP systems verifying that each system has performed in the manner intended for the 6 months prior to submission of the Statement of Qualifications.

86.10 SUBMITTALS

Submit the following documents, test, drawings, and calculations for review and approval prior to installations and procurement.

Engineering

a. Detailed Installation drawings

b. Design Calculations

c. Electrical Wiring Diagrams

d. Soil Thermal Conductivity Test Results / Reports

e. Well and Piping System Layout Drawings

f. System Diagrams

Product Data

Provide Technical Datasheets of the following for review and approval prior to installations and procurement.

a. Refrigerants

b. Ground Heat Exchanger Piping System;

c. Thermally-Enhanced Bentonite Grout;

d. High Grade Bentonite Grout;

e. Cementitious Thermally Enhanced Grout;

f. Closed Circuit Coolers;

g. Plate Heat Exchangers;

h. Heat Tape;

i. Antifreeze;

j. Pumps;

k. Pipe, Fittings, and Piping Components;

l. Expansion Tanks;

m. Air Separators;

n. U-Bend Assemblies;

For the pipe and piping components submittal, include recommendations for the connection of joints, including the preparation of joints for the electrofusion process.

Test Reports

a. Plate Heat Exchangers - Field Acceptance Test Plan;

b. Plate Heat Exchangers - Field Acceptance Test Report;

Certificates

a. Qualifications Of Ground Heat Exchanger Fabricators;

b. Qualifications Of Ground Heat Exchanger Installers;

c. Qualifications of Ground Source Heat Pump Installer. A letter not later than 14 days after the Notice to Proceed, providing the name and Statement of Qualifications of the individual(s) who will serve as Ground Source Heat Pump (GSHP) Installer.

d. Hydrostatic Test

System Designer

a. A letter no later than 14 days after the Notice to Proceed providing the name and Statement of Qualifications of the individual who will prepare the Design and Calculations.

b. System Designer Design Certification;

c. Concurrent with submittal of the Detail Drawings, submit certification by the System Designer that the design and calculations conform to all contract requirements, including signed approval of the Test Reports.

d. Work Coordination and Performance Certificate;

e. Ground Source Heat Pump Installation Certificate;

f. Well Driller License;

g. Pump Installer License;

h. Well Construction Permit;

i. Approved Well Permit;

j. Well Construction Log Record;

k. Ozone Depleting Substances Technician Certification

Manufacturer's Instructions

a. Water-Source Water-to-Air Heat Pumps - Installation Instructions

b. Water-Source Water-to-Water Heat Pumps - Installation Instructions

c. Closed Circuit Coolers - Installation Instructions

d. Plate Heat Exchangers - Installation Instructions

e. Heat Tape - Installation Instructions

f. On-Site Training;

Operation and Maintenance Data

a. Plate Heat Exchangers

b. Heat Tape

c. As-Built Drawings

d. Ground Heat Exchanger Piping System As-Built Drawings

86.11 QUALITY ASSURANCE

Material and Equipment Qualifications

Provide materials and equipment that are standard products of manufacturers regularly engaged in the manufacture of such products, which are of a similar material, design and workmanship. Standard products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use shall include applications of equipment and materials under similar circumstances and of similar size.

The product shall have been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period.

Alternative Qualifications

Products having less than a two-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturer's factory or laboratory tests, can be shown.

Service Support

The equipment items shall be supported by service organizations. Submit a certified list of qualified permanent service organizations for support of the equipment which includes their addresses and qualifications. These service organizations shall be reasonably convenient to the equipment installation and able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

Manufacturer's Nameplate

Each item of equipment shall have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable. As applicable the Energy Star label also affixed to the equipment.

Ground Heat Exchanger Piping System As-Built Drawings

Provide dimensioned as-built drawings of each complete ground heat exchanger piping system, depicting its relationship to other utilities and buildings in its proximity before burying, covering, or concealing.

Drawings shall be of a quality equivalent to the contract design drawings. The as-built drawings of the installed ground heat exchanger piping system shall be laminated or stored in a clear plastic envelope and affixed visibly to the heat pump unit or on the wall in the mechanical room if serving a system of multiple heat pumps. As-built drawings shall be submitted with operation and maintenance data. A permanent label shall be affixed to each heat pump unit indicating basic information for that unit. The information shall include:

a. Nominal flow rate (l/s)

b. Pressure drop (kPa)

c. Temperature drop/rise (degree C)

d. Capacity (W)

System Diagrams

After completion, but before final acceptance, submit System diagrams that show the layout of equipment, piping, and circulation pumps, and typed condensed operation manuals explaining preventative maintenance procedures, methods of checking the system for normal, safe operation, and procedures for safely starting and stopping the system shall be framed under glass or laminated plastic. After approval, these items shall be posted where directed.

Plastic Piping Heat Fusion Requirements

All plastic pipe shall be cut, made up, and installed in accordance with the pipe manufacturer's recommendations. Heat joining shall be performed in accordance with ASTM D2657. Electrofusion joining shall be performed in accordance with ASTM F1290. Qualifications for plastic pipe fabricators are given in this section under paragraph QUALIFICATIONS OF GROUND HEAT EXCHANGER FABRICATORS. Heat fusion tests shall be conducted to verify the quality of the joints.

Qualifications of Ground Heat Exchanger Fabricators

The only acceptable method for joining buried pipe systems is by a heat fusion process. Submit documentation substantiating the following qualifications: ground heat exchanger fabricators shall have completed a heat fusion school in which each participant has performed a heat fusion procedure under direct supervision of an approved manufacturing certification program, or a certified heat fusion technician.

Qualifications of Ground Heat Exchanger Installers

Submit documentation substantiating the following qualifications: installers shall have completed an approved manufacturer's certification program and shall have successfully completed at least two projects with ground heat exchanger work similar in size and complexity to that required for this project within the last 4 years. In documentation submit licensing requirements as regulated by local and state regulations for well drillers and pump installers. Submit for each well driller, the Well Driller license. For each pump installer, submit the Pump Installer License. Certification and licenses for each well driller and pump installer shall be in the state where the work occurs. All required certification and licenses shall be kept current. Out of date licenses and certification will not be accepted. Submit to contracting officer for approval the licenses and certification.

DELIVERY, STORAGE, AND HANDLING

Materials delivered and placed in storage shall be stored with protection from the weather, excessive humidity variation, excessive temperature variation, dirt, dust and/or other contaminants. Proper protection and care of material before, during and after installation is the Contractor's responsibility. Any material found to be damaged shall be replaced at the Contractor's expense. During installation, piping shall be capped to keep out dirt and other foreign matter.

Storage facilities shall be classified and marked in accordance with NFPA 704 or equivalent. Materials shall be stored with protection from puncture, dirt, grease, moisture, mechanical abrasions, excessive heat, ultraviolet (UV) radiation damage, or other damage. Pipe and fittings shall be handled and stored in accordance with the manufacturer's recommendation. Plastic pipe shall be packed, packaged and marked in accordance with ASTM D3892. Upon delivery of piping, fitting, components, and equipment to the site, inspect items for damage and verify items meet project requirements.

86.12 PROJECT/SITE CONDITIONS

Verification of Dimensions

The Contractor shall become familiar with all details of the work, verify all dimensions indicated in the field, and advise the Contracting Officer of any discrepancy before performing any work.

Drawings

Because of the small scale of the drawings, it is not possible to indicate all offsets, fittings, and accessories that may be required. The Contractor shall carefully investigate the plumbing, fire protection, electrical, structural and finish conditions that would affect the work to be performed and shall arrange such work accordingly, furnishing required offsets, fittings, and accessories to meet such conditions.

Accessibility

Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves, expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

86.13 COORDINATION OF WORK AND SYSTEM PERFORMANCE

a. Pump supports, piping offsets, fittings, and any other accessories required shall be furnished as required to provide a complete installation and to eliminate interference with other construction.

b. Submit a Work Coordination and Performance Certificate. Concurrent with submittal of the Detail Drawings and the Calculations, submit a Certificate by both the System Designer and the Ground Source Heat Pump Installer stating that the drawings and calculations have been coordinated with all related work and the Ground Source Heat Pump System will perform as specified and indicated.

c. Submit a Ground Source heat Pump Installation Certificate. Concurrent with submittal of the Test Reports, submit certification by the Ground Source Heat Pump Installer stating that the Ground Source Heat Pump System and related work is installed in accordance with the contract requirements, including signed approval of the test reports.

Article II. PART 2 PRODUCTS

86.14 INTRODUCTION

Energy consuming products and systems shall meet or exceed the performance criteria for ENERGY STAR qualified or FEMP-designated products as long as these requirements are nonproprietary. The FEMP and ENERGY STAR product requirements are available on the web at www.eere.energy.gov/femp/procurement and www.energystar.gov/products. Where ENERGY STAR or FEMP products are not applicable, energy consuming products and systems shall meet the requirements of ASHRAE 90.1 - SI ASHRAE 90.1 - IP

86.15 EQUIPMENT

Refrigerants containing chlorofluorocarbons (CFC) are prohibited. Provide refrigerants, or refrigerants with ozone depleting potential (ODP) of 0.0. Provide SDS Sheets for all refrigerants.

Ground-Source Heat Pumps (GSHP)

Provide ground-coupled closed-loop water-to-water heat pump (extended range) units factory assembled, designed, tested, and rated in accordance with ISO 13256-2. Units shall be listed in ISO 13256-2. Units shall include compressor, reversing valve, expansion valve, refrigerant-to-water condensing coil, refrigerant-to-water evaporator coil, desuperheater, hose kits, dampers, bypass for flushing and purging, and controls. A permanent label shall be affixed to each heat pump unit indicating basic information for that unit. The information shall include: nominal flow rate l/s, pressure drop kPa, temperature drop/rise degree C, and capacity W.

a. Cabinet: Provide manufacturer's standard stainless-steel cabinet finished with corrosion resistant epoxy coating or lacquer acrylic. Provide access panels for inspection and access to internal parts. Insulate cabinet with minimum 12 mm multi-density, fiberglass insulation. Provide copper or stainless-steel female threaded pipe connections for supply water and return water connections; these connections shall be mechanically fastened to the cabinet. Water piping shall be insulated.

b. Compressor: Provide hermetically sealed type compressor, installed on vibration isolators enclosed in an acoustically treated enclosure. Provide high- and low-pressure switches, low suction temperature cut-out, motor thermal overload protection, 5 minute anti-recycle timer, and start capacitor kit. Provide capability to reset compressor lockout circuit at the remote thermostat and at the disconnect. Provide units with factory installed sound attenuation package.

c. Reversing Valve: Provide solenoid activated refrigerant reversing valves energized only during the cooling mode and designed to fail in the heating position.

d. Refrigerant-to-Water Heat Exchangers: Provide refrigerant-to-water heat exchangers of coaxial type (tube-in-tube), with inner [cupronickel][copper] water tube and outer steel refrigerant tube. The refrigerant side of the heat exchanger shall be tested and rated for 3102 kPa refrigerant working pressure. The water side of the heat exchanger shall be tested and rated for 2758 kPa working pressure. A parallel capillary tube/thermal expansion valve assembly shall provide superheat over the entire liquid temperature range. Refrigerant-to-water heat exchangers and refrigerant piping shall be insulated to prevent condensation on the piping containing low temperature water.

e. For heat pump units serving a ground-loop application, the inlet water temperature range to the heat exchanger shall be 7 to 32 degree C liquid temperature range. Show these ranges on the drawings.

f. For closed loop systems, consider copper/steel coaxial heat exchangers (water/refrigerant).

g. For ground, surface water or standing column well applications, consider cupronickel/steel coaxial heat exchangers.

h. Extended range heat pumps usually provide performance in the range of 25 to 100 degrees F range.

i. Low temperature applications such as boiler and closed loop cooling tower or dry cooler usually provide performance in the range of 40 to 110 degrees F range.

j. Factory-Installed Domestic Hot Water Desuperheater: Provide desuperheater of vented double-wall construction and factory installed within indoor heat pump cabinet. Desuperheater units shall be factory assembled, designed, tested, and rated.

Provide with the desuperheater, factory-installed water pump powered by a sealed magnetic drive motor, water line thermostat, secondary safety thermostat to prevent scalding, internal fuse, internally mounted disconnect switch, outside air thermostat, manual on-off switch, low refrigerant gas temperature limit switch, air bleed port, and refrigerant ports. Units shall be UL listed. Desuperheater units shall be UL listed. Units shall be provided by the [ground source closed loop heat pump manufacturer.

Controls: The manual on- off switch shall be a push button type with a cover. An indicating light shall be provided next to the switch to indicate the desuperheater pump energized mode. Provide an outside air thermostat with sun shield set for 4-degree C. The outside air thermostat de-energizes the desuperheater pump. Provide in the water return to the desuperheater unit, a high-water temperature limit with adjustable settings, which de-energizes the desuperheater pump at 60-degree C. Also provide low refrigerant gas temperature limit which de-energizes the desuperheater pump and is set to open at 38-degree C.

NOTE: Provide on the drawings a sequence of operation and control schematic for the heat pump and desuperheater.

k. Hose Kits: Kits shall include two 0.6 m long metal (stainless steel) braided hoses with swivel connectors on one end, flow control valve with test ports, two shutoff ball valves with memory stops (one with test port), blow down ball valve, and Y-strainer. Hoses shall be fire rated to meet UL 94. Hoses shall have a maximum working pressure of 2067 kPa.

   The functionality of the hose kits are:

   - Allow ease and convenience of maintenance and installation of the heat pump units.
   - The hose kits allow the ease and convenience of purging and flushing of the system piping.
   - The hose kits also minimize vibration transmission from the heat pump units to the system piping.

l. Bypass for Purging and Flushing: Provide a bypass around the heat pump unit condenser coil. The bypass includes isolation valves and piping that allows for purging and flushing of the system piping. Provide the necessary flushing pump, hoses, and isolation valves.

m. Hanger Kits: Provide units with hanger kits consisting of galvanized steel brackets, bolts, washers, and vibration isolators. The hanger kit shall be designed to support the unit from below and suspend from threaded rods.

n. Controls: Controls and safety devices shall be factory wired and mounted within the control box of the unit cabinet.

o. Provide a microprocessor-based controller. The microprocessor shall control sequencing, high- and low-pressure switch monitoring, freeze protection, lockout control, night setback, emergency shutdown, short cycle protection, random start, LED mode and fault indicators, fault memory, input and output diagnostics, and a communications port. Provide a factory-installed low voltage terminal block for field control wiring and a low voltage transformer. Provide communications capability for remote direct digital control (DDC). Use standard communication protocol such as LonWorks, BACnet, or other protocol. Provide a hand held, remote service terminal from the heat pump manufacturer capable of interfacing with heat pump unit microprocessor controller to perform diagnostics, data retrieval, and calibration functions.

p. Provide 24-volt electromechanical controls supplied with a low voltage transformer, pump relay, controls for compressor, reversing valve coil, and lock out relay. Controls shall include a random start relay, a night setback relay, and a compressor cycling relay for demand load shedding, and a condensate overflow switch. Provide a low voltage terminal block for field control wiring.

q. Space Temperature Controls: Provide electronic multi-stage, auto-changeover, adjustable thermostats with OFF-HEAT-AUTO-COOL-EMERGENCY system switch and AUTO-ON fan switch. Thermostats shall be furnished by the unit manufacturer. Provide relays, transformers, contractors, and control wiring between thermostats and unit. Thermostats shall read out in degrees C.

Plate Heat Exchangers

Plates, frames, and gaskets shall be designed for a working pressure of 2.07 MPa and factory tested at 31.0 MPa. Medium temperature water, low temperature water, and pressure relief valve connections shall be located in accordance with the manufacturer's standard practice. Connections larger than 80 mm shall be ASME 2.07 MPa flanged. Plates shall be corrugated Type 316 stainless steel or nickel-iron-chromium alloy conforming to ASTM B424.

Pumps

In-Line Pumps

Provide pumps constructed of manufacturer's standard materials suitable for chilled water and hot water heating systems. Pumps shall have mechanical seals and drip-proof electric motors. Motors one Hp and greater shall be the premium efficiency type in accordance with NEMA MG 1.

End Suction Water Pumps

Pumps shall be single stage centrifugal, with mechanical seals and drip-proof electric motors. Motors one Hp and greater shall be the premium efficiency type in accordance with NEMA MG 1. Impeller shall be bronze. Other pump parts shall be manufacturer's standard materials provided with bronze impeller pump. Provide threaded suction and discharge pressure gage tapping with square-head plugs. Provide flexible coupling with steel cover guard on base-mounted pumps. Base-mounted pump, coupling guard, and motor shall each be bolted to a fabricated steel base which shall have bolt holes for securing base to supporting surface.

Close-coupled pump shall be provided with integrally cast or fabricated steel feet with bolt holes for securing feet to supporting surface.

Provide pump suction diffuser. Casing of the pump suction diffuser shall include an angle type body of cast iron. Unit shall have internal straightening vanes, strainer with minimum 6.35 mm openings, and auxiliary disposable fine mesh strainer which shall be removed 30 days after start-up. Provide warning tag for operator indicating scheduled date for removal. Casing shall have connection sizes to match pump suction and pipe sizes, and be provided with adjustable support foot or support foot boss to relieve piping strains at pump suction. Blowdown port and plug shall be provided on unit casing. Provide a magnetic insert to remove debris from system.

Pump Factory Assembled

Provide pump module package with all necessary fittings and valves.

Provide field assembled pump units/components. Provide pump units factory designed, assembled, and pressure tested. Units shall include flanged pumps, brass fill and purge valves, quick release fill and purge ports, pressure/temperature (Pete's) plug, wiring, and fuse protection. Pumps shall be the wet rotor and single stage types, with pump casings thermally insulated. Provide manufacturer's standard galvanized steel cabinet, finished with corrosion resistant epoxy paint.

Pump units shall be provided by the ground source, closed loop heat pump manufacturer.

86.16 ELECTRICAL WORK

Provide electrical motor driven equipment specified complete with motors, motor starters, and controls as specified in other sections of the specifications. Provide high efficiency type, single-phase, fractional-horsepower alternating-current motors, including motors that are part of a system, in accordance with NEMA MG 11. Provide polyphase, squirrel-cage medium induction motors, including motors that are part of a system, that meet the efficiency ratings for premium efficiency motors in accordance with NEMA MG 1. Provide motors in accordance with NEMA MG 1 and of sufficient size to drive the load at the specified capacity without exceeding the nameplate rating of the motor.

Motors shall be rated for continuous duty with the enclosure specified. Motor duty requirements shall allow for maximum frequency start-stop operation and minimum encountered interval between start and stop. Motor torque shall be capable of accelerating the connected load within 20 seconds with 80 percent of the rated voltage maintained at motor terminals during one starting period.

Motor bearings shall be fitted with grease supply fittings and grease relief to outside of the enclosure.

Manual or automatic control and protective or signal devices required for the operation specified and any control wiring required for controls and devices specified, but not shown, shall be provided. For packaged equipment, the manufacturer shall provide controllers including the required monitors and timed restart.

Where two-speed or variable-speed motors are indicated, solid-state variable-speed controller may be provided to accomplish the same function. Use solid-state variable -speed controllers for motors rated 7.45 kW (10 hp) or less and adjustable frequency drives for larger motors. Provide variable frequency drives for motors as specified on other sections of the specifications.

86.17 ABOVEGROUND PIPING SYSTEMS

Provide above ground piping as specified on HVAC specifications.

86.18 GROUND HEAT EXCHANGER PIPING SYSTEM

Provide high density polyethylene pipe, fittings, and piping components for the underground portions of the ground heat exchanger. Use of polyvinyl chloride (PVC) or polybutylene pipe and fittings is not permitted. Provide high density polyethylene pipe coiled on reel, with U-bend factory installed, pipe pre-marked for depth, and U-bend connections factory tested. Because of their size and weight, coiled PE piping require appropriate equipment and procedures for safe handling, installation, and use. Reels and coiled pipe shall allow easy and through inspection of the pipe exterior for any shipping and handling damage. The reel shall be capable of securing the pipe coil while the pipe is being pressure tested. The reel and pipe coil shall allow easy access and handling while spooling the pipe coil off the reel for insertion into the bore hole. Pipe coil on reel shall be factory marked to show depth graduations.

High Density Polyethylene Pipe

Pipe shall be manufactured from virgin high density polyethylene extrusion material in accordance with ASTM D2513 with PE345434C or PE355434C cell classification and UV stabilizer of C, D, or E as specified in ASTM D3350. Provide ASTM D3035 pipe with a standard dimension ratio (SDR) of 11.0 for pipe less than 32 mm diameter.

Provide ASTM D2447, Schedule 40 or ASTM D3035 pipe with a minimum SDR of 13.5 for pipe 32 mm diameter or greater, and a minimum SDR of 17.0 for pipe 75 mm diameter or greater.

Provide ASTM D3035 pipe in vertical bores greater than 60 m and up to 107 m deep with a SDR of 11.0.

Provide ASTM D3035 pipe in vertical bores greater than 107 m deep with a SDR of 9.0.

Fittings

Provide ASTM D3261 butt and saddle fusion fittings and ASTM D2683socket fusion fittings manufactured in accordance with ASTM D2513. Barbed fittings, compression type fittings, mechanical joint fittings, grove fittings, and hose clamps are not permitted in polyethylene [or polybutylene] pipe systems. All pipe fittings underground shall be fusion type joints. Flange joints and fittings shall not be provided on underground piping.

Threaded Transition Fittings

Provide ASTM D2513 reinforced threaded steel / brass]-to-polyethylene fittings. Fittings shall have a factory applied external epoxy coating.

86.19 PIPING ACCESSORIES

Pipe Hangers and Supports

Provide MSS SP-58 and MSS SP-69. Type 1 with adjustable type steel support rods, except as specified or indicated otherwise. Attach to steel joists with Type 19 or 23 clamps and retaining straps. Attach to Steel W or S beams with Type 21, 28, 29, or 30 clamps. Attach to steel angles and vertical web steel channels with Type 20 clamp with beam clamp channel adapter. Attach to horizontal web steel channel and wood with drilled hole on centerline and double nut and washer. Attach to concrete with Type 18 insert or drilled expansion anchor. Provide Type 40 insulation protection shields for insulated piping.

Strainers

ASTM A126, Class B, flanged iron body, for 65 mm and larger. ASTM B62, cast iron or bronze for 50 mm 2 inches and smaller. Provide basket or Y type. Tee type is acceptable for water service. Provide screens constructed of bronze, monel metal, or 18-8 stainless steel, free area not less than 2.5 times pipe area, with perforations as follows:

a. 80 mm and smaller: 1.1 mm diameter perforations for liquids.

b. 100 mm and larger: 3.2 mm diameter perforations for liquids.

Pressure Gages

Provide single style pressure gage with 115 mm dial, brass or aluminum case, bronze tube, gage cock, pressure snubber, and syphon.

Provide scale range for intended service. Gages shall have an accuracy of 0.5 percent of the span. Provide gages that have a dial layout with major ticks with numbers every 10 pressure units and minor ticks every one pressure unit. Provide pressure gages with dual range dials, kpa and psi.

Pressure/Temperature Test Provisions

Provide 15 mm MPT by 75 mm long, brass body and cap, with retained safety cap, nordel self-closing valve cores, permanently installed in piping where shown, or in lieu of pressure gage test connections shown on the drawings.

Testing Accessories

Provide one each of the following test items to the Contracting Officer:

a. 8 mm FPT by 3.2 mm diameter stainless steel pressure gage adapter probe for extra-long test plug.

b. 90 mm diameter, one percent accuracy, compound pressure gage, 0 to 1378 kPa range.

c. minus 29 to 49 degree C pocket thermometer one-half degree accuracy, 25 mm, 127 mm long stainless-steel stem, stainless steel wetted materials, and stainless-steel external materials.

Thermometers

Provide bi-metal dial type thermometers with stainless steel case, stem, and fixed thread connection; 75 mm diameter dial with glass face gasketed within the case; and accuracy within 2 percent of scale range. Provide scale range for intended service.

Flexible Pipe Connectors

Provide flexible bronze or stainless-steel piping connectors with single braid where indicated. Connectors shall be suitable for the intended service.

Expansion Tanks

Construct of steel for minimum working pressure of 862 kPa (gage). Tank shall have polypropylene or butyl lined diaphragm which keeps the air charge separated from the water.

Air Separators

Provide tangential inlet and outlet connections, blowdown connections, and internal perforated stainless steel air collector tube to direct released air to automatic air vent. Construct of steel for minimum working pressure of 862 kPa (gage). Design to separate air from water and to direct released air to automatic air vent. Unit shall be of one-piece cast-iron construction with internal baffles and two air chambers at top of unit; one air chamber shall have outlet to expansion tank and other air chamber shall be provided with automatic air release device. Unit shall be for minimum working pressure of 862 kPa (gage).

Tracer Wire for Nonmetallic Piping

Provide bare copper or aluminum wire not less than 2.5 mm in diameter in sufficient length to be continuous over each separate run of nonmetallic pipe.

U-Bend Assemblies

Provide factory-assembled and fused injection-molded 180-degree U-bend assemblies equipped with anti-buoyancy devices. U-bend assemblies shall be used for the vertical well field vertical loop heat exchangers. U bend assemblies shall be prefabricated assemblies with u-bends and continuous pipe. The assemblies shall be pre-marked [by the manufacturer] with depth graduations. Each assembly shall be the indicated length of the vertical loop heat exchanger as indicated. Each assembly shall be factory pressure tested to 689.5 kPa gage. Each assembly shall be provided with a factory pressure test report. Each U-bend assembly shall be temporarily capped to prevent the entry of dirt during storage and installation.

Pipe Casings

Provide rigid nonmetallic conduit and fittings (PVC) as pipe casings at floor penetrations and underground building entries for the entry of ground heat exchanger piping. The conduit shall serve as a casing for ease of installation and removal of the piping into the building. The pipe casing diameter shall be at least 4 times the diameter of the carrier pipe to allow "pulling the pipe through the casing. Provide rigid nonmetallic conduit and fittings specified complete with fittings and necessary hardware.

Carrier Pipe Size		Casing Size	
(mm)	(Inches)	(mm)	(Inches)
19	3/4	100	4
25	1	100	4
32	1-1/4	100	4
38	1-1/2	150	6
50	2	200	8

Building Surface Penetrations

Except as indicated otherwise, provide pipe sleeves as specified in this section. Provide where piping passes entirely through walls, ceilings, roofs, and floors. Secure sleeves in position and location during construction. Provide sleeves of sufficient length to pass through entire thickness of walls, ceilings, roofs, and floors. Provide 25 mm minimum clearance between exterior of piping or pipe insulation, and interior of sleeve or core-drilled hole.

Sleeves shall not be installed in structural members except where indicated or approved. Except as indicated otherwise piping sleeves shall comply with requirements specified. Sleeves in non-load bearing surfaces shall be galvanized sheet metal, conforming to ASTM A653/A653M, Coating Class G-90, 1.0 mm. Sleeves in load bearing surfaces shall be uncoated carbon steel pipe, conforming to ASTM A53/A53M, Schedule 30 Standard weight. Sealants shall be applied to moisture and oil-free surfaces and elastomers to not less than 13 mm depth. Sleeves shall not be installed in structural members.

Each sleeve shall extend through its respective wall, floor, or roof, and shall be cut flush with each surface. Sleeves shall be of such size as to provide a minimum of 6.35 mm all-around clearance between bare pipe and sleeves or between jacketed-insulation and sleeves. Except in pipe chases or interior walls, the annular space between pipe and sleeve or between jacket over-insulation and sleeve shall be sealed.

Sleeves in Masonry and Concrete

Provide steel standard weight / PVC standard weight pipe sleeves. Pipes passing through concrete or masonry wall or concrete floors or roofs shall be provided with pipe sleeves fitted into place at the time of construction. Sleeves are not required where piping passes through concrete floor slabs located on grade. Core drilling of masonry and concrete may be provided in lieu of pipe sleeves when cavities in the core-drilled hole are completely grouted smooth.

Waterproof Penetrations

Pipes passing through roof or floor waterproofing membrane shall be installed through a 5.17 kg/sq. m. copper sleeve, or a 0.81 mm thick aluminum sleeve, each within an integral skirt or flange.

Flashing sleeve shall be suitably formed, and skirt or flange shall extend not less than 200 mm from the pipe and be set over the roof or floor membrane in a troweled coating of bituminous cement. The flashing sleeve shall extend up the pipe a minimum of 50 mm above the roof or floor penetration. The annular space between the flashing sleeve and the bare pipe or between the flashing sleeve and the metal-jacket-covered insulation shall be sealed as indicated. Penetrations shall be sealed by either one of the following methods.

a. Waterproofing Clamping Flange: Pipes up to and including 250 mm in diameter passing through roof or floor waterproofing membrane may be installed through a cast iron sleeve with caulking recess, anchor lugs, flashing clamp device, and pressure ring with brass bolts. Waterproofing membrane shall be clamped into place and sealant shall be placed in the caulking recess.

b. Modular Mechanical Type Sealing Assembly: In lieu of a waterproofing clamping flange, a modular mechanical type sealing assembly may be installed. Seals shall consist of interlocking synthetic rubber links shaped to continuously fill the annular space between the pipe/conduit and sleeve with corrosion protected carbon steel bolts, nuts, and pressure plates. Links shall be loosely assembled with bolts to form a continuous rubber belt around the pipe with a pressure plate under each bolt head and each nut.

After the seal assembly is properly positioned in the sleeve, tightening of the bolt shall cause the rubber sealing elements to expand and provide a watertight seal rubber sealing elements to expand and provide a watertight seal between the pipe/conduit seal between the pipe/conduit and the sleeve. Each seal assembly shall be sized as recommended by the manufacturer to fit the pipe/conduit and sleeve involved. The Contractor electing to use the modular mechanical type seals shall provide sleeves of the proper diameters.

Fire-Rated Penetrations

Penetration of fire-rated walls, partitions, and floors shall be sealed as specified in related sections of the specifications.

Escutcheon Plates

Provide one piece or split hinge metal plates for piping entering floors, walls, and ceilings in exposed spaces. Provide polished stainless-steel plates or chromium-plated finish on copper alloy plates in finished spaces. Provide paint finish on metal plates in unfinished spaces.

HEAT TAPE

Provide UL listed parallel conduction type heat tape, with electrical characteristics indicated, and adjustable thermostat for outdoor aboveground winterized piping. The tape shall not be affected by direct sunlight, ambient temperature, operating temperature, rain, or salt laden atmosphere.

Heat Tape Construction

Provide flexible, parallel circuit construction consisting of a continuous self-limiting resistance, conductive inner core material between two parallel copper bus wires, designed for cut-to-length at the job site and for wrapping around valves and complex fittings. Self-regulation shall prevent overheating and burnouts even where the cable overlaps itself.

a. Provide end seals for ends of circuits. Wire at the ends of circuits is not to be tied together.

b. Provide sufficient cable, as recommended by the manufacturer, to keep the pipe surface at 1.1 degrees C minimum during winter outdoor design temperature as indicated, but not less than the following:

- 80 mm pipe and smaller with 25 mm thick insulation,
- watts/0.3 m 4 watts/feet.
- 100 mm pipe and larger 38 mm thick insulation, 8 watts/0.3 m of pipe.

Electrical Accessories

a. Power supply connection fitting and stainless-steel mounting brackets. Provide stainless steel worm gear clamp to fasten bracket to pipe.

b. 13 mm wide fiberglass reinforced pressure sensitive cloth tape to fasten cable to pipe at 305 mm intervals.

c. Pipe surface temperature control thermostat shall be cast aluminum, NEMA 4 (watertight) enclosure, 15 mm NPT conduit hub, SPST switch rated 20 amperes at 480 volts ac, with capillary and copper bulb sensor. Set thermostat to maintain pipe surface temperature at not less than 1.1 degrees C.

d. Signs shall be manufacturer's standard, stamped "ELECTRIC TRACED" located on the insulation jacket at 3 mm intervals along the pipe on alternating sides.

86.20 ACCESS DOORS FOR VALVES

Provide factory fabricated and primed flush face steel access doors including steel door frame equipped with continuous hinges and turn-screw-operated latch. Provide door frame installation in plaster and masonry walls. Provide access door size as indicated. Provide insulated fire rated access doors as indicated. Fire rated doors shall meet UL 10B. Doors shall be rated for 1-1/2 hours.

86.21 AUXILIARY DRAIN PAN, DRAIN CONNECTIONS, AND DRAIN LINES

Provide galvanized steel auxiliary drain pans under units where indicated. Provide separate drain lines for the unit drain and auxiliary drain pans. Drain pans shall be fully and freely draining in compliance with ASHRAE 62.1. Trap drain pans to ensure complete pan drainage. Provide drain lines full size of drain opening.

86.22 ANTIFREEZE PROTECTION

Provide ethylene glycol / propylene glycol antifreeze fluid in a water-based solution which meets local, State, and Federal requirements and is acceptable to heat pump component manufacturers. The antifreeze and water-based heat transfer fluid shall be used in closed-loop ground source heat pump systems for the transfer of energy to provide heating and cooling. The heat transfer fluid shall contain the necessary corrosion inhibitors to protect pipe and equipment from attack by the antifreeze solution utilized. The mixture of antifreeze and corrosion inhibitors in a water-based solution is defined as a heat transfer fluid.

Biodegradability

The heat transfer fluid shall not be less than 90 percent biodegradable.

Properties of the heat transfer fluid

The heat transfer fluid shall conform to the following requirements, and tests shall be performed in accordance with specified test methods on the fluid.

Flash Point

The flash point of the heat transfer fluid shall not be lower than 90 degrees C, determined in accordance with ASTM D92.

Biological Oxygen Demand (BOD)

For 5 days the BOD, at 10 degrees C, shall not exceed 0.2-gram oxygen per gram nor be less than 0.1-gram oxygen per gram.

Freezing Point

The freezing point shall not exceed minus 9 degrees C, determined in accordance with ASTM D1177.

Toxicity

The toxicity shall not be less than LD 50 (oral-rats) of 5 grams per kilogram. The NFPA hazardous material rating for health shall not be more than 1 (slight).

Storage Stability

The heat transfer fluid, tested in accordance with ASTM F1105, shall neither show separation from exposure to heat or cold nor show an increase in turbidity.

Quality

The heat transfer fluid, shall be homogeneous, uniform in color, and free from skins, lumps, and foreign materials detrimental to usage of the fluid.

86.23 CHEMICAL FEED PROVISIONS

Provide chemical feed provisions as specified in other section of this specification package.

Aboveground Condenser Water Piping System

Add borate-nitrite corrosion inhibitors, acceptable to heat pump component manufacturers, to initial fill water for heating and cooling water systems in concentrations of 0.0039 liter/liter of system water if corrosion inhibitors are not contained in freeze protection solution in the ground heat exchanger loop.

Chilled/Hot Water Piping System

Add borate-nitrite corrosion inhibitors, acceptable to heat pump component manufacturers, to initial fill water for heating and cooling water systems in concentrations of 0.0039 liter/liter of system water if corrosion inhibitors are not contained in freeze protection solution in the ground heat exchanger loop.

Ground Heat Exchanger Piping

Provide corrosion inhibitors acceptable to heat pump manufacturers with concentrations suitable for each system and appropriate for the antifreeze used.

86.24 PAINTING OF NEW EQUIPMENT

New equipment painting shall be factory applied or shop applied, and shall be as specified herein. New equipment surfaces constructed of non-ferrous surfaces and materials do not have to be factory or shop painted.

Factory Painting Systems

Manufacturer's standard factory painting systems may be provided subject to certification that the factory painting system applied will withstand 125 hours in a salt-spray fog test, except that equipment located outdoors shall withstand 3000 hours in a salt-spray fog test. Field applied coatings are not acceptable. Provide a factory coating system on the fins of exterior heat transfer equipment that meets ASTM B117.85 salt-fog test duration for 3000 hr. Salt-spray fog test shall be in accordance with ASTM B117, and for that test the acceptance criteria shall be as follows: immediately after completion of the test, the paint shall show no signs of blistering, wrinkling, or cracking, and no loss of adhesion; and the specimen shall show no signs of rust creepage beyond 3 mm on either side of the scratch mark.

The film thickness of the factory painting system applied on the equipment shall not be less than the film thickness used on the test specimen. If manufacturer's standard factory painting system is being proposed for use on surfaces subject to temperatures above 50 degrees C, the factory painting system shall be designed for the temperature service.

Shop Painting Systems for Metal Surfaces

Clean, pretreat, prime and paint metal surfaces; except stainless steel, aluminum, or bronze alloy surfaces need not be painted. Apply coatings to clean dry surfaces. Clean the surfaces to remove dust, dirt, rust, oil and grease by wire brushing and solvent degreasing prior to application of paint, except metal surfaces subject to temperatures in excess of 50 degrees C shall be cleaned to bare metal.

Where more than one coat of paint is specified, apply the second coat after the preceding coat is thoroughly dry. Lightly sand damaged painting and retouch before applying the succeeding coat. Color of finish coat shall be aluminum or light gray.

a. Temperatures Less Than 50 Degrees C: Immediately after cleaning, the metal surfaces subject to temperatures less than 50 degrees C shall receive one coat of pretreatment primer applied to a minimum dry film thickness of 0.0076 mm, one coat of primer applied to a minimum dry film thickness of 0.0255 mm; and two coats of enamel applied to a minimum dry film thickness of 0.0255 mm per coat.

b. Temperatures Between 50 and 205 Degrees C: Metal surfaces subject to temperatures between 50 and 205 degrees C shall receive two coats of 205 degrees C heat-resisting enamel applied to a total minimum thickness of 0.05 mm.

c. Temperatures Greater Than 205 Degrees C: Metal surfaces subject to temperatures greater than 205 degrees C shall receive two coats of 315 degrees C heat-resisting paint applied to a total minimum dry film thickness of 0.05 mm.

86.25 BENTONITE GROUT

Provide bentonite grout mixture for pressure grouting and sealing the bore hole of the vertical well. Provide grouting of wells in accordance with IGSHPA 21015. The grout selected shall meet NSF/ANSI 60. The grout shall meet all local and state rules and regulations. The bentonite will be a slurry that will be tremie grouted from the bottom of the boring to the surface in accordance with the IGSHPA installation manual. The contractor will work quickly to assure that there are no air voids forming as a result of the bentonite placing.

High Grade Bentonite Grout

Provide high grade bentonite grout mixture. The grout shall be mixed with potable water. The grout shall be mixed per manufacturer instructions.

The thermos-conductivity of the grout shall be 0.744 W/mK (0.43 Btu/hr-ft-F) or greater. The minimum solids content shall be 23 percent. The target grout weight shall be 1140 kg/m3 (9.5 lb/gallons) to 1176 kg/m3 (9.8 lb/gallon).

Thermally-Enhanced Bentonite Grout

Provide thermally enhanced bentonite grout mixture. Thermally enhanced bentonite grout mixture shall be a high solids bentonite grout. The grout shall be mixed per the manufacturer instructions. Potable water shall be used for mixing the grout. Grout shall have a minimum solids content of 65 to 70 percent. The thermal conductivity of the grout mixture compound shall be a minimum of 1.73 W/mK (1.0 Btu/hr-ft-F) or greater. The target grout weight shall be 1596 kg/m3 (13.3 lb/gallons) to 1728 kg/m3 (14.4 lb/gallon). The thermally-enhanced bentonite grout shall have a thermal enhancement compound consisting of a high-grade silica compound that constitutes a minimum of 50 percent by weight of the aqueous slurry.

Cementitious Thermally Enhanced Grout

Provide Cementitious Thermally Enhanced Grout mixture. The cementitious thermally enhanced grout mixture shall be a high solids sodium bentonite grout with portland cement, potable water, silica sand compound, and a super plasticizer compound. The grout shall be mixed per the manufacturer instructions. Potable water shall be used for mixing the grout. The thermal conductivity of the grout mixture compound shall be a minimum of 2.42 W/mK (1.4 Btu/hr-ft-F) or greater. The target grout weight shall be 1920 kg/m3 (16 lb/gallon).

86.26 CONTROLS

Controls for the ground-loop heat pump systems complete and ready for operation shall be integrated with the HVAC system controls package / Integrated Building Management System. Systems include heat pumps, system equipment, piping, pumps, electrical equipment, controls, wells, and condenser.

Controls shall be designed in accordance with the manufacturer's recommendations and to comply with the sequence of controls shown on the drawings.

PART 87 - PART 3 EXECUTION

87.1 INSTALLATION

Heat Pump System

Maintenance access to each piece of equipment shall not be compromised by any type of piping, electrical conduit, or any other utility. Further, install equipment in accordance with IS Electrical Wiring Standards and with the manufacturer's written installation instructions, including the following:

a. Ground-source water-to-water heat pumps - installation instructions

b. Plate Heat Exchangers - installation instructions

c. Heat Tape - installation instructions

d. As-Built Drawings of the installed systems. As-built drawings shall also show and document the as-constructed locations of the well field with dimensions, including all wells and loop fields.

Connections to Existing Systems

Notify the Client in writing at least 15 calendar days prior to the date the connections are required. Obtain approval before interrupting service. Furnish materials required to make connections into existing systems and perform excavating, backfilling, compacting, and other incidental labor as required. Furnish labor and tools for making actual connections to existing systems. Flush existing systems in accordance with paragraph FLUSHING THE GROUND HEAT EXCHANGER prior to making connections.

87.2 ABOVEGROUND PIPING

Provide above ground piping as specified on related sections of this specification package.

a. Cleaning of Piping: Keep interior and ends of new piping and existing piping, affected by Contractor's operations, cleaned of water and foreign matter during installation by using plugs or other approved methods. When work is not in progress, securely close open ends of pipe and fittings to prevent entry of water and foreign matter. Inspect piping before placing into position.

b. Flushing and Purging of Piping: Before connection of the header to the polyethylene ground heat exchanger loops, flush and purge the entire aboveground piping system thoroughly in accordance with IGSHPA 21020 recommendations and leave filled with clean water. If the header is not immediately joined to the ground heat exchanger loop, the open ends shall be taped or capped. Purge and vent the above ground system piping of all air.

87.3 EARTHWORK

Earthwork shall be performed in accordance with applicable provisions of related sections of this specification package, except that bentonite and thermally enhanced grouts shall be used where indicated.

87.4 GROUND HEAT EXCHANGER PIPING

Examine areas and conditions under which ground heat exchanger systems will be installed. Prior to excavation, trenching, or drilling, locate and mark buried utilities. Do not proceed with work until approved by the Contracting Officer. Sharp bends and mitered joints shall not be used in piping. Provide fittings for changes in direction when minimum bend radius, as recommended by the pipe manufacturer, is exceeded. All pipe bends shall be radius type elbows. Make changes in piping sizes through tapered concentric fittings. Leaks shall be "cut-out" and repaired in accordance with the pipe manufacturer's recommendations. Direct buried threaded or flanged connections are not permitted. Prior to installation of the ground heat exchanger systems, verify that the installers are certified Ground Heat Exchanger Installers. Inspect all piping for damage prior to installation. Installation shall follow IGSHPA guidelines as well as local, state, and Federal guidelines and regulations. Upon delivery of piping, inspect the pipe for damage and verify that the pipe meets the project specifications. Prior to installation of pipe, carefully inspect pipe for damage. Do not use the pipe if it has a cut or a gouge that is more than 10 per cent of the minimum wall thickness of the pipe. Provide reels and pipe coil. Reels shall be used to securely hold the pipe coil while being pressure tested. When inserting the pipe into the bore hole, spool off pipe from the reel into the hole.

Vertical Well Fields

The designer shall become familiar with the local and state regulations regarding geothermal wells and water wells. The designer shall modify these specifications in accordance to the local and state regulations. The designer shall design and specify the heat exchanger systems to meet the specific local and state regulations and statutes that may be required, such as:

a. Well driller licensing and certification

b. Pump installer licensing

c. Well construction permit

d. Local and/or State approved well permit

e. Allowable grout requirements

f. Allowable heat transfer fluids

g. Allowable pipe materials

h. Well construction log record

i. Well abandonment and abandonment records

j. Well closing and closing records.

k. Antifreeze fluids, if any

l. Water treatment chemicals, if any

m. Corrosion inhibitors, if any

n. Groundwater conservation

o. Protection of different aquifers

p. Authorization to install and operate

Each vertical well and ground heat exchanger loop shall have a Well Construction Permit as required by local and state regulations. In addition, each well and ground heat exchanger loop shall have a local [and] [or] state Approved Well Permit as required by local and state regulations. The contractor shall maintain these permits during the construction contract period. A copy of the permits shall be submitted with the As-built documentation. Construction and installation of each well shall be in accordance to these permits. Each well shall be performed by a state certified well driller. Certifications shall be in the state where the work occurs. Prior to installation of wells, verify the well drillers and pump installers are certified. For any well that is abandon, abandonment shall be performed in accordance to local and state regulations. Provide abandonment records with certification to the contracting officer for review and submittal to the state. For any well that is closed, closing shall be performed in accordance to local and state regulations. Provide closing records with certification to the contracting officer for review and submittal to the state. All well submittals and records shall have the names of the well drillers and pump installers, copies of their certifications.

Each U-bend loop shall be factory assembled, laid out straight, taped to reduce spring back, and water pressure tested at 689 kPa (100 psi) for leaks and flow by IGSHPA 21020 recommended procedures before the hole is bored. Comply with all local and state codes, regulations, and requirements during the construction of the vertical wells or bore holes. Submit for each vertical well a Well Construction Log Record.

a. The borehole shall be constructed as indicated. Where any discrepancy exists between local and state codes, regulations, and requirements and this specification, the more stringent requirement applies. The U-bend shall be factory assembled and pressure tested to 100 psig prior to insertion into the vertical bore. All connections shall be by heat fusion. When inserting the U-bend assembly into the bore hole, use the depth graduations as another means of verification of depth of the bore hole. There shall be no joint in either leg of each vertical loop except for the factory assembled connection at the U-bend.

b. Vertical bores shall be 1.5 m 5 feet deeper than the length of the U-bend assembly loop and shall be clean (no casing) and of sufficient diameter to facilitate the installation of the U-bend assembly and a third pipe for pressure grouting. Fill the loop with water and pressurize to 276 kPa (40 psi) to prevent the pipe from being crushed by backfill material. Temporarily cap the ends of the U-bend assemblies until the actual testing begins. The cap shall be fused to the pipe end in order to hold the pressure. Pressure testing can be performed while the bore hole is being drilled.

c. Backfill the bores from the bottom up with a bentonite grout material and grouting process in conformance with IGSHPA 21010 to ensure pipe contact and compliance with local and State requirements for sealing. Bentonite grout shall be prepared and mix in accordance with manufacturer's recommendations for water-to-mix ratio. Grouting materials shall be placed using a pressure pump with a tremie pipe system. Install the grouting material from the bottom to the top of the vertical borehole. If ant settling occurs during the initial 24-hour period after installation, additional material shall be added to ensure the grouting material remains at the desired surface level. The bores shall not contain large, sharp, or jagged rocks or debris. Take reasonable and prudent care during installation and backfilling to not crush, cut, or kink the pipe.

d. In the event that a geological formation is encountered, that prevents the grouting material from forming a solid seal, either a 9.5 mm (3/8 inch) or 19 mm (3/4 inch) cementitious bentonite grout material may be used to seal the specific formation zone. Notify the contracting officer of any problems encountered. Upon completion of the specific zone, resume grouting until the desired surface of the vertical well or bore hole is reached.

e. During installation of the vertical well, maintain a water and soils log. The log shall indicate depth of water encountered, materials encountered, depth intervals of materials and physical description. If water is encountered, indicate in the log the depths at which it was encountered, and the static water level. Include in the log the type of drill rig used, the actual drilling time to complete the bore hole.

f. In absence of other requirements or as indicated, provide u-bend assemblies having the following pipe diameters for the u-bend assembly length as follows:

- 19 mm diameter for 30 to 60 m loop length
- 25 mm diameter for 45 to 90 m loop length
- 32 mm diameter for 76 to 150 m loop length

g. Each well location shall be shown and identified on as built drawings. Provide a tracer wire system. The tracer wire system shall include a locator device to identify the well field. The locator device shall be located in the mechanical room.

h. Minimum vertical well distance: In absence of other requirements or as indicated, provide a minimum well separation distance between wells of 4.572m. Provide a minimum separation distance between wells and building foundation walls of 6.0 m.

Horizontal Well Fields and Header Piping

Horizontal trenches for ground heat exchanger piping may be dug with a chain type trenching machine or a backhoe. The piping shall be buried a minimum of 1.2 m (48 inches) deep or as indicated. Make joints while pipe is laying beside the trench. If the soil contains rocks, dig the trench 152 mm (6 inches) deeper than required and install a base of 152 mm (6 inches) of fines or sand before placing the pipe. [Buried piping in systems containing antifreeze and installed within 1.5 m (60 inches) of any building wall, structure, or pipe shall be insulated with R-2 minimum closed cell insulation.] After the piping is installed, tested, and flushed, purged, inspected, and approved while still under pressure, backfill 152 mm (6 inches) above with fines or sand. Complete backfill in accordance with IGSHPA 21020 recommended procedures. When laying pipe in trench, ensure the bottom of the trench is smooth, free from rocks and debris. When laying pipe, use a fine to medium backfill to fill trench. If there are multiple pipes in the trench, ensure each pipe is completely surrounded and supported with backfill before the next pipe is installed.

Piping at Building Entries

Install a rigid non-metallic conduit (PVC) as a pipe casing at building entries and floor penetration. The casing allows ease of installation of the ground heat exchanger piping into the building. The conduit should extend 610 mm (24 inches) from the building foundation. The conduit should end 152 mm (6 inches) above the floor. The ends of the conduit where the pipe is located, fill the annular space with insulation and a silicone seal.

Polyethylene Piping

Install piping in accordance with manufacturer's written instructions. Polybutylene piping shall not be used. Piping components shall be joined by a heat fusion method that conforms the piping manufacturer's recommendation for this application. During installation, keep trash, soil, and foreign objects out of the pipe. Tape or cap ends of the pipe until the pipe is joined to the circuit. The vertical loop take-off tee fittings may be made using tee fittings or the saddle fusion process on header piping 32 mm (1.25 inches) diameter and above. Completely remove the cutout on the saddle tees. Use bell reductions at pipe reductions. Use reducing socket tees when fabricating socket type reducing headers. Avoid sharp bends and mitered elbows and bends in piping. Consult pipe manufacturer for minimum bend radius. Install elbow fittings at changes in pipe direction that are tighter than the minimum recommended bend radius. Use only continuous pipe in vertical U-bend loops.

Heat Fusion Process

Joining shall be either by butt, socket, or saddle (for sidewall applications only) fusion in accordance with the manufacturer's Heat Fusion Qualification Guide. Use socket fusion joints for pipe 20 mm (3/4 inches) diameter and less. Use butt fusion joints for pipe greater than 20 mm (3/4 inches) diameter. Different plastics or grades of plastic shall not be fused together. When fusing pipe, perform heat fusion tests to verify the quality of the joints. Notify the Contracting Officer, the results of the heat fusion test.

Pressurizing

After assembly of the entire ground loop system, fill the system with water and pressure test to 689 kPa (100 psi). Visually inspect welds prior to backfill of the trenches.

Pipe Identification

Install metalized (detectable) warning and identification tape above each horizontal pipe run. Install tape a minimum of 152 mm (6 inches) below finish grade. Install mechanical identification of vertical bore holes and connecting headers.

Tracer Wire

Install a continuous length of tracer wire for the full length of each run of nonmetallic pipe. Attach wire to top of pipe in such manner that it will not be displaced during construction operations. Provide a tracer wire system with a locator device for identifying the well field.

Threaded Fittings

Threaded joints shall be sealed with a sealant compatible with the circulating fluid; use of lubricating tape for sealing is not permitted. Do not thread metal pipe into plastic pipe or vice versa. Direct buried threaded joints are not permitted. Threaded joints may be used only above grade, within mechanical spaces, or within valve pits.

87.5 FIELD PAINTING AND FINISHING

Requirements for field painting and finishing are specified on related sections of this specification package.

87.6 FLUSHING AND PURGING GROUND HEAT EXCHANGER

Before connection of the plastic ground heat exchanger loops to the header, flush and purge each loop thoroughly in accordance with IGSHPA 21020 recommendations and leave filled with clean water. If the loop is not immediately joined to the header, it shall be taped or capped. Purge and vent the ground heat exchanger system piping of all air.

87.7 ADJUSTMENTS

Adjust controls and equipment so as to give satisfactory operation. Adjust entire water temperature control system and place in operation so that water quantities circulated are as indicated. Adjust and balance air duct systems so that air quantities at outlets are as indicated and so that distribution from supply outlets is free from drafts and has uniform velocity over the face of each outlet.

87.8 INSTRUCTING OPERATING PERSONNEL

Upon completion of work and at time designated by Contracting Officer, provide services of water source heat pump manufacturer's technical representative for period of not less than one 8-hour working day for instruction of Government operating personnel in proper operation and maintenance of equipment.

87.9 FIELD QUALITY CONTROL

Upon completion and before final acceptance of work, test each system in service to demonstrate compliance with the contract requirements. Adjust controls and balance systems prior to final acceptance of completed systems. Test controls through every cycle of operation. Test safety controls to demonstrate performance of required function. Correct defects in work provided by Contractor and repeat tests. Furnish fuel, water, electricity, instruments, connecting devices, and personnel for tests.

Flush and clean piping before placing in operation. Clean equipment, piping, strainers, ducts, and filters. Perform and document that proper Indoor Air Quality During Construction procedures have been followed; this includes providing documentation showing that after construction ends, and prior to occupancy, new replaceable filters were provided and installed and permanent filters were cleaned.

Piping Systems Except for Ground Heat Exchanger and Refrigerant

For above ground piping systems, and steel or copper piping systems: Before insulating, hydrostatically test each new piping system at not less than 1.5 times the system working pressure / 1296 kPa gage (188 psi) based on 1.5 times a system pressure of 862 kpa gage (125 psig). Maintain pressure for 2 hours with no leakage or reduction in gage pressure.

Obtain approval before applying insulation.

Flow Test of Ground Heat Exchanger Piping

Before backfilling the trenches, flush, purge, and vent systems of air and flow test to ensure all portions of the heat exchanger are properly flowing using the procedures recommended by IGSHPA 21020. Utilize a portable temporary purging unit consisting of the following:

a. High volume, high head purge pump

b. Open reservoir

c. Filter assembly with bypass

d. Flow meter

e. Pressure gage

f. Connecting piping

g. Connecting hoses

Using a purge pump and the procedures recommended by IGSHPA 21020, flush and purge each ground heat exchanger system until free of air, dirt, and debris. A velocity of 0.6 m/sec (2 feet/sec) is required in pipe sections to remove the air. Purge and vent all air from the piping.

Perform the flushing and purging operation with the water source heat pumps isolated by shutoff valves from the ground heat exchanger system. Allow purge pump to run 15 minutes after the last air bubbles have been removed. After the ground heat exchanger is completely flushed of air and debris, open the isolation valves and permit circulation through the heat pumps until the entire system is flushed and purged.

Utilizing the purging unit and the procedures recommended by IGSHPA 21020, conduct a pressure and flow test on the ground heat exchanger to ensure the system is free of blockage. If the flow test indicates blockage, locate the blockage using the manufacturer's recommendation, remove the blockage, then repeat the purge procedure and conduct the pressure and flow test again until all portions of the system are free flowing. The flow test shall be observed and approved by the Contracting Officer.

After purging has been completed, add the required amount of antifreeze to the system to achieve the required solution concentration. Fill the open reservoir with the quantity of antifreeze required for minus 9 degree C (15-degree F) freeze protection and run the purge pump 15 minutes to deliver the antifreeze to the system. Test the solution with a hydrometer to determine the actual freezing point.

Form 1, "Ground Heat Exchanger Inspection and Test Report" located below, shall be completed for each system by the Contractor after completion of the flow and injection of required antifreeze to the system and before the systems can be backfilled.

FORM 1

GROUND HEAT EXCHANGER (GHX) INSPECTION AND TEST REPORT

NOTE: Use separate form for each GHX loop system.

Building:____ Inspection Date:______ Ground Heat Exchanger No. or Description:____

Does the ground heat exchanger have a Well Construction Permit:____________Permit No.__________

Does the ground heat exchanger have an approved well permit__________Permit No._________

List the WSHP Unit No.'s served by this GHX: _____________

Ground Heat Exchanger Design Water Flow - ___________ liters/sec gpm

Calculated purging flow and press to achieve 0.61 m 2 feet/sec

Purging:

Flow ___________ liters/sec gpm Head _____________ kPa psi, Duration of test________ min.

Hydrostatic test pressure ___ kPa psi; Duration _____ min.

Did the system pass the pressure test? __________ Is antifreeze required in system?_ If yes, was antifreeze measured?______

Has a dimensioned drawing been prepared, completely and accurately showing the layout of the ground heat exchanger? __________

Does the layout differ substantially from the contract documents? _________ If so, is the deviation approved? _

Depth of installed vertical loops is ___m feet. (Design is ____ m feet.)

Depth of horizontal piping is _______m feet. (Design is _____m feet.)

Are the trenches clear of sharp bends, rocks, or other sharp objects that could restrict flow?___

Are all joints heat fused (butt-, socket-, or saddle-fusion)?____

Do the joints have the proper amount of roll-out?_____

Has the piping material been cut-out and properly removed from saddle-fusion tees?__

Grout Manufacturer? _____________;

Percent of solids used in grout?____________Grout Type?___Grout Thermal conductivity, k? (give units) ____

Was the system backfilled properly with good clean backfill material?_________

Attach the soil boring and water well log sheet for the bore hole?_For each well submit a Well Construction Log Record

Comments: ____________________________________

Inspected and approved this _____________ date by ________ Title: ________

Pressure Test of Ground Heat Exchanger Piping

Prior to any cover or backfill of bore holes or trenches and after flow testing, flushing, and purging, the ground heat exchanger piping and headers shall be pressure tested by hydrostatic test. The system shall be isolated from all connections to piping. Ensure that the piping system has been flushed of all dirt and debris. The piping shall then be plugged or capped as necessary in preparation for the hydrostatic test(s).

Hydrostatic Test

The piping shall be hydrostatically pressurized to 150 percent of system pressure or 1000kPa (150 psi) and monitor piping. If there is any pressure loss or visible leakage during the testing, the leak shall be identified and repaired in accordance with the piping components manufacturer's recommendations. Test shall be repeated until there is no loss in pressure during the test period. Provide results of test in test report. During testing, do not exceed the pipe/pipe fitting manufacturer test pressure rating [or 150 percent of the pipe pressure rating]. Do not pneumatic test the pipe. Prior to testing, remove all air from the system. Provide test in accordance to IGSHPA standards.

Refrigerant Piping Pressure Test and Evacuation

Perform the following when field piping connections are provided.

a. Pressure Test: Test refrigerant piping using dry, oil-free nitrogen, and prove tight at 2068 kPa (300 psi) on the high side and 1027 kPa (150 psi) on the low side. Maintain pressure for 2 hours with no leakage or reduction in gage pressure.

b. Evacuation: Use a high vacuum pump and certified micron gage to reduce the absolute pressure on both sides of system simultaneously to 300 microns. After reaching this point charge system with proper refrigerant until pressure of 0 kPa is obtained. Repeat evacuation-charging procedure for two more cycles, totaling to three evacuation-charging cycles. On final evacuation, secure pump and maintain 300 microns for 2 hours before charging with required final refrigerant.

Equipment Tests

Field Testing

Test each item of equipment in operation, for continuous period of not more than 24 hours under every condition of operation in accordance with each equipment manufacturer's recommendation. Verify that each item of equipment operating parameters is within limits recommended by the manufacturer.

Field Test Plans

Furnish water-source heat pump and closed-circuit cooler field test plans developed by each equipment manufacturer detailing recommended field test procedures for each item of equipment. Field test plans developed by the installing Contractor, or the equipment sales agency furnishing the equipment will not be acceptable. The Contracting Officer will review and approve the field test plan for each item of equipment listed below prior to commencement of field testing of the equipment.

Equipment Items to Test:

a. Ground-source water-to-water heat pumps - field acceptance test plan

b. Plate Heat Exchangers - field acceptance test plan

Coordinated Testing: Indicate in each field test plan when work required by this section requires coordination with test work required by other specification sections. Furnish test procedures for the simultaneous or integrated testing of equipment controls which interlock and interface with controls factory prewired or external controls for the equipment.

Prerequisite Testing: Equipment for which performance testing is dependent upon the completion of the work covered within Testing, Adjusting and Balancing of HVAC System. Indicate in each field test plan when such prerequisite work is required.

Test Procedure: Indicate in each field test plan each equipment manufacturer's published installation, start-up, and field acceptance test procedures. Include in each test plan a detailed step-by-step procedure for testing automatic controls provided by the manufacturer. Each test plan shall include the required test reporting forms to be completed by the Contractor's testing representatives. Structure procedures to test the controls through all modes of control to confirm that the controls are performing with the intended sequence of control. Controllers shall be verified to be properly calibrated and have the proper set point to provide stable control of their respective equipment.

Performance Variables: Each test plan shall list performance variables that are required to be measured or tested as part of the field test. Include in the listed variables performance requirements indicated on the equipment schedules on the design drawings. Furnish with each test procedure a description of acceptable results that have been verified. Identify the acceptable limits or tolerances within which each tested performance variable shall acceptably operate.

Job Specific: Each test plan shall be job specific and shall address the particular item of equipment and particular conditions which exist with this contract. Generic or general preprinted test procedures are not acceptable.

Specialized Components: Each test plan shall include procedures for field testing and field adjusting specialized components, such as hot gas bypass control valves, or pressure valves.

Field Test Reports

Equipment Items to Test:

a. Ground-source water-to-water heat pumps - field acceptance test report

b. Plate Heat Exchangers - field acceptance test report

Manufacturer's Recommended Test: Conduct the manufacturer's recommended field testing in compliance with the approved test plan specified above. Furnish a factory trained field representative authorized by and to represent the equipment manufacturer at the complete execution of the field testing.

Operational Test: Conduct a standard [continuous 24 hour] operational test for each item of equipment. Equipment shutdown before the test period is completed shall result in the test period being started again and run for the required duration. For the duration of the test period, compile an operational log of each item of equipment. Log required entries every 2 hours. Use the test report forms for logging the operational variables.

Notice of Tests: Conduct the manufacturer's recommended tests and the operational tests; record the required data using the approved reporting forms. Notify the Contracting Officer in writing at least 15 calendar days prior to the testing. Within 30 calendar days after acceptable completion of testing, submit each test report for review and approval.

Report Forms: Type data entries and writing on the test report forms. Completed test report forms for each item of equipment shall be reviewed, approved, and signed by the Contractor's test director and the QC Manager. The manufacturer's field test representative shall review, approve, and sign the report of the manufacturer's recommended test. Signatures shall be accompanied by the person's name typed.

Deficiency Resolution: The test requirements acceptably met; deficiencies identified during the tests shall be corrected in compliance with the manufacturer's recommendations and corrections retested to verify compliance.

Additional Field Testing

Requirements for testing, adjusting, and balancing of ducts, piping, and equipment are specified on Section TESTING, ADJUSTING, AND BALANCING FOR HVAC System. Testing, adjusting, and balancing shall begin only when the entire HVAC system, including controls, has been completed with the exception of performance tests. Where required the heat pump systems shall be charged with premixed antifreeze solution with type and concentration as indicated prior to testing, adjusting, and balancing.

Balance air flows to that indicated in accordance with SMACNA 1966, as supplemented and modified by this section. Testing, adjusting, and balancing shall begin only when the entire HVAC system, including controls, has been completed with the exception of performance tests. Where required the heat pump systems shall be charged with premixed antifreeze solution (type and concentration as indicated prior to testing, adjusting, and balancing). Submit written certificate to report the following:

a. Water source heat pump unit nameplate data, and actual voltage and ampere consumption.

b. Supply and return terminal airflow, and equipment used to measure airflow.

c. Water source heat pump liters/sec and entering and leaving air temperatures.

d. Water source heat pump unit condenser water liters/sec and entering and leaving temperatures.

e. Ambient outside air temperature, date, and person testing, balancing, and reporting.

Soil Thermal Conductivity Testing

Perform soil thermal conductivity testing of the well system project location. The test will establish the thermal properties for design of the well field and the subsurface conditions at the site. The test will be performed by performed under the supervision of and certified by the ground source heat pump (GSHP) specialist. The test will be performed at [multiple] locations as [indicated] [determined by the designer]. Each test will contain a minimum of 48 hours of recorded data. The test shall be used for verification of the design and installation.

Soil Thermal Conductivity Testing Set-up

Conduct and perform tests in accordance with the procedures outlined in ASHRAE Item 90376.

Data Recording and sensor accuracy

Record data by means of automatic data logging equipment intended for such purposes and suitable for service of local ambient outside conditions.

Protect compensated thermocouple reference junctions, if used, either from separate from the data logging equipment or integral to it, from rapid changes in environmental conditions. Record data at uniform 5 minute] time intervals during the 72-hour test period. Data recorded will include a minimum time, inlet and outlet temperatures, heater power input, circulating pump power input, and ambient temperatures.

Temperature Measurements: Measure inlet and outlet temperatures with immersion temperature sensors. The temperatures sensors shall be calibrated every six months and have a valid calibrated stamp.

Include the date and results from the most recent calibration in the test report. Any change-out of the temperature sensor in the system or data logger will require re-calibration.

Temperature Sensor calibration and accuracy: The combined rated sensor and data logger accuracy will be as indicated plus or minus 0.5 degrees C (1 degree F) or better. Verify temperature sensor and data logger accuracy and calibration at first use of the testing device during the test. The testing equipment shall have been calibrated semi-annually by immersion in ice and water bath. A calibration certificate stamp with date shall be on the test device. The result from the verification test using ice water bath shall not differ from 0 degrees C (32 degrees F) by more than the required data accuracy. Additional readings will not differ from one another by more than plus or minus 0.2 degrees C (0.5 degrees F) when simultaneously immersed in the ice bath.

Power Measurements: Measure heater and circulating pump power input. Power measurements shall be independently determined by using power transducers with the manufacturer stated accuracy of plus or minus two percent or better at the level of power consumption for the test.

Flow Rate Measurements: Measure the flow rate. Flow rate shall be measured using a variable flow meter calibrated by the flow meter manufacturer having a rated accuracy of plus or minus two percent of full scale. Full scale or maximum rated flow for the flow meter shall not exceed actual flow rate by more than 70 percent.

Test Borehole Construction

Prepare the bore hole in a manner in which the heat exchangers will be ultimately installed to the extent possible with respect to the bore hole size, pipe diameter grouting method, and grout types as indicated. The installation of the test bore hole shall be as indicated for the vertical well field. The bore hole depth shall not vary more than 5 percent from the indicated design depth. Materials of the test borehole and heat exchanger shall be as indicated.

a. At least 2 m of excess pipe shall be left protruding above grade upon completion of the test borehole construction. Temporarily cap the ends of the protruding pipes until the actual testing begins. All local and state codes and regulations will be adhered to during the construction of the test bore hole. Where any discrepancy exists between local codes and regulations and this specification, the more stringent requirement applies. The U-tube assembly shall be factory assembled and pressure tested to 100 psig prior to insertion into the vertical bore. All connections shall be by heat fusion.

b. During the completion of the test borehole, maintain a water well and soils property log. For each well submit a Well Construction Log Record

ON-SITE TRAINING

The System Designer / Ground Source Heat Pump Specialist shall conduct a training course for operating and maintenance personnel as designated by the Contracting Officer. Training shall be provided for a period of 16 hours of normal working time and shall start after the system is functionally complete but prior to the performance tests. The on-site training shall cover all of the items contained in the approved Operation and Maintenance Data packages.

-- End of Section --

XXXIII. UNDERFLOOR RADIANT COOLING (HEATING) SYSTEM

PART 88 - PART 1 GENERAL

88.1 SCOPE

This section relates to RADIANT Under Floor Heating (UFH) system. Main supply and return pipes including valves and fittings, main circulation pump, heat source and all other components required to render the system fully operational are not included in this section.

88.2 REFERENCED CODES AND STANDARDS

The publications listed below form a part of this specification to the extent referenced.

EN 1264-1, 1999	Floor heating: Systems and components - Part 1: Definitions and symbols
prEN 1264-2, 2007:	Prove methods for the determination of the thermal output of floor eating systems using calculation and test methods
EN 1264-3, 1999:	Floor heating: Systems and components - Part 3: Dimensioning
EN 1264-4, 2001:	Floor heating: Systems and components - Part 4: Installation
prEN 1264-5, 2007:	Heating and cooling surfaces embedded in floors, ceilings and walls- Determination of thermal output and cooling output
EN15377-1, 2007:	Design of embedded water-based surface heating and cooling systems: Determination of the design heating and cooling capacity
EN15377-2, 2007:	Design of embedded water-based surface heating and cooling systems: Design, Dimensioning and Installation
EN15377-3, 2007:	Design of embedded water-based surface heating and cooling systems: - Part 3: Optimizing for use of renewable energy sources

88.3 SYSTEM DESCRIPTION

Design, Supply, Install and Commission RADIANT HEATING Tacker system for under floor heating applications. The Complete System shall consist of:

a. RADIANT HEATING pipe, fittings and accessories;
b. RADIANT HEATING tacker sheet;
c. RADIANT HEATING Polyethylene sheet;
d. RADIANT HEATING tacker staples;
e. RADIANT HEATING Joint protection tube;
f. RADIANT HEATING PE-Xa pipe bend support;
g. RADIANT HEATING edge insulation strip and
h. RADIANT HEATING Brass Manifolds

88.4 MANUFACTURERS DOCUMENTATION

The Contractor shall design, execute and commission underfloor heating system in accordance with the Manufacturers' / supplier's documents and instructions.

Installers to be a member of the RADIANT HEATING Authorized Installer Network, familiar with the materials and the techniques specified. The installer is responsible to ensure any equipment connected to the RADIANT HEATING system and supplied by others is suitable for the purpose and installed to manufacturer's requirements. Radiant system including PE-Xa piping, Accessories like Couplers, Connectors, Compression Sleeves, Joint Protection Tubes, Tackernadel clips, Actuator, Manifold, Manifold box, PE foil, Pipe bend support should be of approved make and from same OEM (Original Equipment Manufacturer) only.

88.5 PROJECT SPECIFIC DESIGN PARAMETERS

Pipe material	PE-Xa
Pipe dimensions	20mm x 2.0mm
System	Tacker Sheet
Heating Output	As per BOQ

Covered floor area	As per BOQ
Pipe laying pattern	Reverse Spiral /Double Meander/Single Meander
Pipe spacing	150mm
Number of zones	As per OEM Design
Number of manifolds	As per BOQ/OEM Design
Number of circuits	As per BOQ/OEM Design
Max. length per circuit	100m
Total flow rate	As per OEM Design Output Sheet

88.6 DOCUMENTATION

Design Data

Contractor shall provide design calculations to determine thermal and cooling output in accordance with prEN1264-2, prEN1264-5, EN 15377-1, EN 15377-2, EN-15377-3. Contractor shall provide complete pipe layout drawing and material list for review and approval prior to procurement and installation.

As-Built documents

Installer to provide as-built information to the Client on completion of the UFH/C installation, including:

a. Photographs recording actual layout
b. Drawings showing the as built layout
c. Protocols for Pressure Testing, Warm-up and Commissioning

88.7 MANUFACTURER WARRANTY

a. 1 year warranty period from date of completion of system test, based on the Terms and Conditions of the RADIANT HEATING Warranty Certificate in the manufacturers standard form.
b. Radiant system including but not limited to PEX-a piping, Accessories like Couplers, Connectors, Compression Sleeves, Joint Protection Tubes, Tackernadel clips, Room Thermostat, Slab temperature Sensor, Wiring Controller & Actuator should be of approved make OEM only.
c. Radiant system OEM/Supplier need to furnish at least one Completion Certificate from Indian Government/Corporate end user where Radiant Heating/Cooling system should be in running condition for at least 5 Years. Radiant System OEM/Supplier may arrange Site visit of End user or its representative within India free of cost for at least 2 Persons if agreed.
d. Only Authorized installer of Radiant System OEM will be allowed to install/commission the Radiant system & installer need to furnish Authorized letter from Approved Radiant system OEM during bidding of project.

PART 89 - PART 2 PRODUCTS

89.1 PE-XA CROSS-LINKED POLYETHYLENE PIPE

Pipe materials shall be a PE-Xa peroxide crosslinked polyethylene with thermal & mechanical memory effect, inner layer and an outer red/orange/other adhesive for clear distinction as radiant heating/cooling pipe. Suitable for use in heating and cooling applications in residential and commercial applications in accordance with BS EN 1264 and BS 7291. Pipe shall be as per DIN CERTCO and Watermark certifications.

Pipe performance Specification

Product	PE-Xa Pipe for RADIANT HEATING SYSTEM
Colour	As per OEM Standard
Material	Flexible, high-pressure cross-linked polyethylene pipe PE-Xa (in accordance with DIN 16892/16893)
Design pressure	C Class 5/8bar (in accordance with ISO 15875)
Continuous operation	70 °C at 300 kPa (3 bar)
Maximum operating pressure	600 kPa (6 bar)
Maximum operating temperature	90 °C
Short-term maximum temperature	100 °C
Operational life time (at 70°C / 300 kPa)	50 years
Available sizes in mm	16 x 2.0, 20 x 2.0mm
Impact toughness at 20°C and -20°C	Without breaking
Linear Thermal expansion coefficient	0.15
Thermal Conductivity	0.35 W/m-K
Pipe roughness	0.007mm
Minimum Bending radius without aid	5 x d (When laid at temperature > 0°C)

Fittings and sleeves

Connections shall be axial compression sleeve mechanism, featuring the following benefits:

a. Permanently sealing compression sleeve jointing technique
b. Self-sealing pipe material – connection without the use of an O-ring
c. Increased hydraulic properties based on expansion technology
d. Approved for flush-mounted installation
e. Robust jointing technique highly suitable for construction sites
f. Simple visual inspection
g. Joint can be pressurised immediately after installation
h. Requires no calibration or deburring

Fittings and sleeves shall be made of brass with silver surface finish.

89.2 RADIANT HEATING TACKERNADEL SYSTEM

Tacker sheet

Expanded polystyrene EPS insulation sheet laminated with a fabric reinforced foil made from polyethylene to RADIANT Cooling/Heating requirements. The water-resistant foil prevents moisture and water from the screed reaching the EPS floor insulation. Thickness 25-30mm, 24-30 KG/m3 Density.

Pipe fixing staples:

Pipe fixing staples to fasten the pipe firmly to the Tacker sheet and to prevent the pipe from floating.

Edge insulation strips

To prevent sound and heat bridges. Made of closed cell polyethylene foam, with profiled wall, a self-adhesive strip on back and foil flaps. The tear-proof foil flaps with self-adhesive film base prevents moisture and water from the screed reaching the EPS floor insulation.

PE-Xa Pipe bend support

To guide PE-Xa pipes, Temperature resistance from -5°C to 60°C, Material – Polyamide

Pipe Joint Protection tube

Joint Protection tubes for 20mm PE-Xa pipe as protection in the conduit entries for heating/cooling circuit, Material - Polyethylene, design according to DIN 49019, Heat resistance of up to +105°C.

89.3 RADIANT HEATING MANIFOLD

Manifolds shall be installed at a location approved by the Architect/OEM. The number of manifold outlets shall correspond to the number of circuits served by that manifold.

RADIANT HEATING manifold manufactured from standard Stainless steel/Brass as a distributor and collector for the individual heating and cooling circuits. Pre-assembled and mounted on sound-insulated galvanised steel brackets. Combined flow meter (if required) 0-5 l / min and quick stop in the supply header. 2 to 12 outlets ¾" male thread euro-cone. Maximum operational pressure 600kPa (6 bar) at 80°C.Manifold should have integrated brass ball valve.

89.4 ZONE CONTROL

Provide control zones with 2-channel timer function with night set-back mode as per the drawings based on the following components:

89.5 ROOM THERMOSTATS

Room Thermostats Standard, Comfort or Control complete with setback temperature reduction mode, including programmable models and models with floor sensor. Operating voltage 24/230 VAC.

89.6 DISTRIBUTION CONTROLLER

Distribution controller, fixed above the manifold, connects wiring from up to 6 room thermostats, up to 14 thermal actuators and optional boiler and pump, and manages the control of the UFH system. Extendable with attachable modules for timer function and further functionality.

a. Colour housing: silver-gray (RAL 7001)
b. Colour cover: transparent.
c. Input voltage 230 VAC
d. Operating voltage 24 VAC
e. Power transformer 50 VA

89.7 THERMAL ACTUATORS

Thermal actuators to allow the individual control of circuits by opening and closing the corresponding isolating valve on the manifold. The RAUMATIC actuator is controlled by room thermostat Standard, Comfort or Control. Operating voltage 24 VAC.

PART 90 - PART 3 EXECUTION

90.1 INSTALLATION

Make sure installation area is fully cleared, flat even floor and surface free of irregularities. Co-ordinate with builder at shop drawing stage to identify all construction joints and saw cuts with concrete floors. Install the manifold straight at the designated position.

Ensure the area for installation remains dry and weathertight by incorporating a damp proof membrane in the floor slab. Lay insulation to the total area of the installation, with edge insulation (if required) on all internal and external wall lines. If the floor construction is a two-part slab with the walls already in place, edge insulation is required around the walls to prevent heat loss up the walls and to allow the screed for expansion.

Confirm suitable insulation material and thickness with RADIANT HEATING design before installation of UFH/C. Lay Tacker sheets tightly butted up to each other over substrate with foil overlapping adjacent sheet. Ensure printed foil faces upwards and the grid lines up across the joints. Stagger the joints as in a brick laying pattern. Tape down foil overlaps so no water will penetrate through the insulation. Fix down pipes to the Tacker sheet with specially designed Tacker staples fixed with a RADIANT HEATING Tacker staple gun to ensure a secure fixing on the Tacker sheet. Staples are specific to the pipe size (grey staples for 17mm pipe and black staples for 20mm pipe). When fixing the pipe, staples should be positioned at a maximum of 400mm centres along the pipe. Mark all heated and non-heated areas and floor joints on the floor area.

90.2 PIPEWORK LAYOUT

Pipework fixed onto the insulation board to OEM or designer's recommendations. Lay pipes in a continuous length from the manifold in the pre-designed configuration. RADIANT HEATING fittings can be embedded into concrete if agreed with designer. Fittings to be wrapped with PVC tape. Pipes start and finish at the manifold position. Pipes must run to the corresponding port on the manifold. Do not cross pipes over in the floor. Note the real pipe length of each circuit to adjust the hydraulic balancing of the manifold. Mark the name of each circuit on the corresponding manifold outlet.

All coils in floors shall be installed strictly in compliance with the requirements of the structural engineer and in accordance with the recommendations of OEM or RADIANT HEATING designer for concrete floor heating applications. Piping shall be installed completely free of twists, warps or buckles. Screed height should provide a minimum thickness of 35mm above the crown of the pipework. Depending on structural loads the screed thickness must eventually be increased.

90.3 CONDUIT SLEEVING

Sleeve all flow pipes with RADIANT HEATING conduit sleeving where the pipe enters and returns from screed/ concrete for the first metre to RADIANT HEATING requirements. Sleeve across construction joints in floor. When installing pipe in door frames or through walls install a section of corrugated sleeving in this area to allow free movement of the pipe.

90.4 CONNECTION TO MAIN SUPPLY AND RETURN LINES

Provide total flow rates and head losses for each manifold to the contractor of the main supply and return lines to enable them to design pump sizes, pipe dimensions and all other components required to render the system operational. The connection of the UFH/C system to the main supply and return pipes is the duty of the mechanical contractor.

90.5 FILLING AND PRESSURE TESTING

Pressure tests the system with water before the slab is laid to ensure all joints are watertight and no damage has occurred to the pipe during installation. In case of freezing conditions, add antifreeze to avoid freezing of the water in the pipes. Make sure antifreeze is suitable for PEX and brass materials. Allow for pressure testing of the underfloor heating pipe circuits to 600kPa. Lay the slab as soon as possible, in good contact to the pipes, without any air pockets, after laying the pipe circuits and completion of a pressure test. Leave pipe circuits under pressure until concrete is cured. Provide signed and witnessed pressure testing protocol.

90.6 COMMISSIONING

Ensure the complete central heating system, including main supply circulation pump and radiators if present, is working. Based on the real pipe length noted during laying of the pipework, adjust each circuit slowly via the valves on the manifold to ensure an even flow and heat up is achieved (hydraulic balancing). Provide commissioning certificate.

------End of Section-------

XXXV. CODES AND STANDARDS (MECHANICAL SERVICES)

PART 91 - GENERAL

91.1 INFORMATION PROVIDED BY THE CONTRACTOR

A. The following details outline the information which the Contractor shall provide during the course of the Contract to suit the master construction programme.

1. Shop Drawings / Working Drawings for all aspects of the installation.
2. Detailed design drawings and equipment schedules for specialist systems as quoted and defined in this specification
3. Comprehensive submissions to local authority organizations for approval.
4. Incoming infrastructure locations to suit infrastructure setting out by provider
5. Builder's work information for holes, plinths, chases, etc.
6. Setting out details and mounting heights
7. Samples
8. Site mark-ups indicating installation details
9. Record drawings, operating and maintenance manual, training documentation, log-books, schematics, mimic diagrams.

B. The Contractor is responsible for detailed builder's work and coordination of wall and floor penetrations through structure including dimensioned drawings showing coordinated setting out. Include full coordination with all facets of the Contract.

91.2 DESIGN STANDARDS

A. Wiring Regulations for Electrical Installations Sixteenth Edition (IEE 17th Edition), published by the Institution of Engineering & Technology (BS 7671), together with all the latest amendments and relevant local authorities' regulation.

B. Hydraulic Institute

C. ANSI - American National Standards Institute

D. NEMA - National Electrical Manufacturers Association

E. UL - Underwriters Laboratories Inc.

F. ETL - Electrical Testing Laboratories

G. CSA - Canadian Standards Association

H. NEC - National Electrical Code

I. ISO - International Standard Organization

J. IEC - International Electro technical Commission

K. AMCA - Air Movement and Control Association, USA

L. BSI - British Standard Institute

M. CIBSE - Chartered Institute of Building Services Engineers

N. ASME - American Society of Mechanical Engineers

O. NFPA - National Fire Protection Association

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

1. Where applicable local authority requirements and specific client instructions will take precedent.

91.3 THE CODES, REGULATION

S.No.	DESCRIPTION	CODES
1	Safety code for air-conditioning (Revised) (Amendment 1)	IS 659: 1964 (reaffirmed 1991)
2	Safety code foe mechanical Refrigeration	IS 660: 1963 (reaffirmed 1991)
3	Testing of refrigeration Compressors	IS 5111: 1993
4	Air cooled heat exchangers (Amendment 1)	IS 10470: 1983 (Reaffirmed 1991)
5	Packaged Air-conditioner (Amendment 1991)	IS 8148: 1976 (Reaffirmed 1991)
6	Hermetic compressors	IS 10617: Part I, II & III 1983
7	Suppliers' data sheet for clean Air equipment (laminar flow)	IS 12357: 1998
8	Thermostats for use in Refrigeration etc. (Reaffirmed 1991)	IS 11338: 1965
9	Code of practice for design and Construction of flue chimneys	IS 11338: 1965 (Reaffirmed 1991)
10	Metal Duct Work	IS 655: 1963
11	Steel for general structural Purpose	IS 2062: 1992
12	Piping Work	IS 1239 Part I & II 1990 / 1992 IS & BS: 3601
13	Welding	IS: 3589
14	Refrigeration Air conditioning & Refrigeration Air-conditioning institute Standards	As per ASHRAE / ISI
15	Hot Dip Zinc Coated Steel Tubes	IS 4736: 1968
16	Gate Valves for Water lines	IS 778: 1980
17	Copper Alloy Gate Globe Check	IS 778: 1980
18	Butterfly Valve	IS 13095: 1991
19	Steel Pipe flanges	IS: 6392
20	Gaskets	IS 638: 1979
21	Mild steel tubes & fittings	IS 1239 Part I & II
22	Dual plate Check Valve for Water Lines	AP: 194
23	Colour code for the identification of pipe lines	IS 2379: 1963
24	HRC Cartridge fuse links Upto 650 Volts	IS 2208: 1976
25	Specific requirements for the Direct switching of the individual motors	IS 4064 (Part II) 1978
26	PVC insulated (HD) Electric Cables for working voltage up Including 1100 Volts	IS: 1554 (Part I)
27	Starter	IS 8554 (Part I) 1979

28	Inspection and testing of Installation	IS 732 (Part III) 1979
29	Galvanized steel wire for fencing	IS 277: 1977
30	Three phase induction motors	IS: 325
31	PVC insulated (heavy duty) Cables for working voltage Up to 1.1. KV and up to 11 KV Grade respectively	IS 1554: 1981 Part I & II
32	Code for practice for electrical Wiring installations	IS 732: 1989
33	Code for practice for earthing	IS 3043: 1966
34	Horizontal centrifugal pumps	IS: 1620
35	Centrifugal fans (1st. Division)	IS 894: 1987
36	Wrought aluminium & aluminium Alloy sheet and strip for general	IS: 737
37	Mild steel tubes, tubular and other Wrought steel fittings	IS : 1239
38	Bourdon tube pressure and vacuum Gauges	IS: 3624
39	Glossary of terms used in refrige-Ration and air-conditioning	IS : 3615
40	Propeller type AC Ventilation fans	IS 2312: 1967
41	Electrical axial flow fans	IS 3588: 1987

91.4 SAFTEY CODES

S.No.	DESCRIPTION	CODE
1	Safety code for mechanical refrigeration	IS 660
2	Safety code for air conditioning	IS 659
3	Safety code for scaffolds & ladders	IS 3696
4	Code of practice for fire precaution in Welding & cutting operations	IS 3016
5	Code for safety procedures and practices In electrical works	IS 5216
6	Code of practice for safety and health	IS 3696

PART 92 - MECHANICAL SYSTEMS

A. The Contractor shall design, supply, install, test, commission and handover the complete mechanical, installations in accordance with the Contract Preliminaries and Conditions and as described within this specification, tender drawings, and applicable sections of the standard specification for Mechanical Engineering Services.

B. The scope of work shall comprise, but not limited to the following:

1. Ground Source Heat Pump System for Cooling
2. Ventilation system
3. Fire & Smoke management systems
4. Potable water systems
5. Hot water systems
6. Waste, sewerage & rain water drainage.
7. Firefighting systems
8. BMS systems

APPENDIX – BUILDING ENVELOPE DATASHEETS

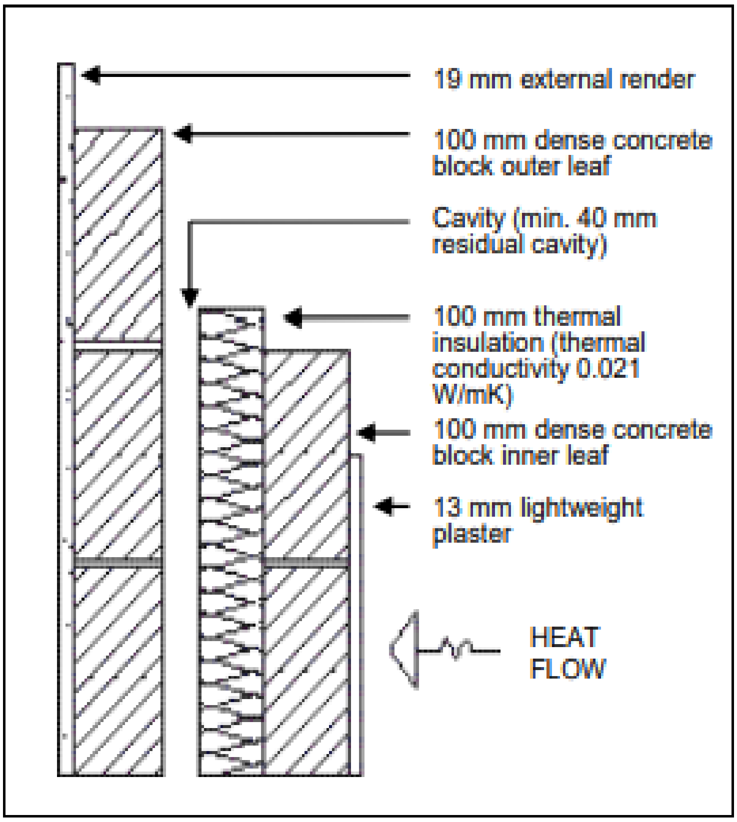
MAT -CV -001

EXTERIOR WALLS COMPOSITION

DATASHEET NO:	MAT-CV-001		
MATERIAL TYPE	EXTERIOR WALLS COMPOSITION		

	SPECIFICATIONS		
SN	Compositions	Thickness(m)	Resistance (m2-K/W)
1	INTERNAL SURFACE		0.13
2	LIGHT WEIGHT PLASTER	0.013	0.072
3	DENSE CONCRETE BLOCK INNER LEAF(ACC)	0.1	0.075
4	THERMAL INSULATION (THERMAL CONDUTIVITY 0.021 W/mK), Expanded polystyrene (EPS)	0.1	4.76
5	CAVITY / Air Gap	0.05	0.44
6	100MM DENSE CONCRETE BLOCK OUTER LEAF	0.1	0.075
7	19MM EXTERNAL RENDER Premixed Sand and Cement Render	0.019	0.019
8	EXTERNAL SURFACE		0.04
	TOTAL WIDTH =	0.382	5.611
		U - VALUE (MINIMUM)	0.18 W-m2/K

IMAGE

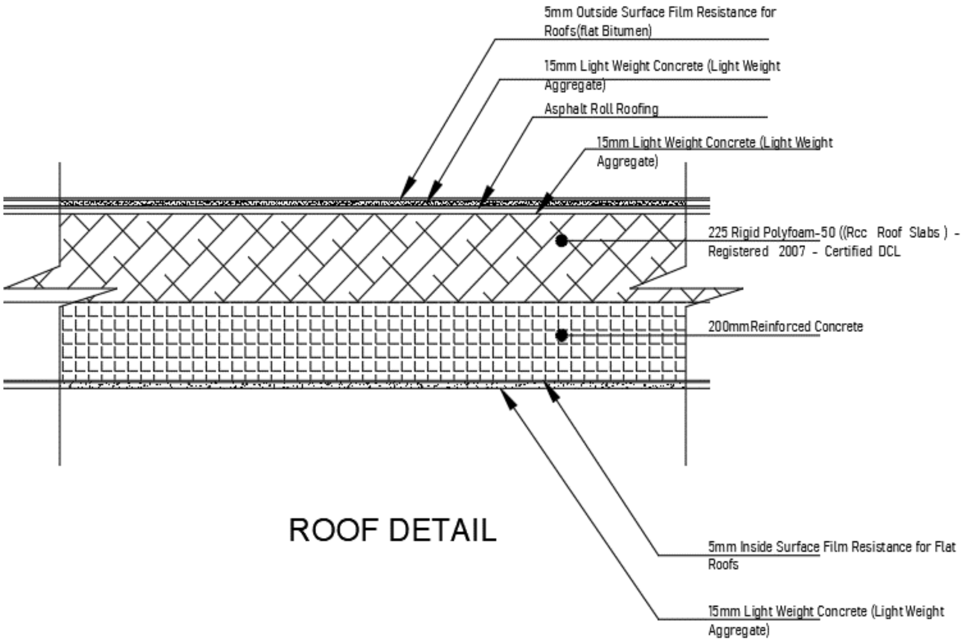


MAT -CV -002

ROOF SLAB COMPOSITION

DATASHEET NO:	MAT-CV-002		
MATERIAL TYPE	ROOF SLAB COMPOSITION		
SPECIFICATIONS			
SN	**Compositions**	**Thickness(mm)**	**Resistance (m2-K/W)**
1	Outside Surface Film Resistance for Roofs(flat Bitumen)	5	0.055
2	15mm Light Weight Concrete (Light Weight Aggregate)	15	0.018
3	Asphalt Roll Roofing	5	0.025
4	Light Weight Concrete (Light Weight Aggregate)	15	0.018
5	Rigid Polyfoam-50 ((Rcc Roof Slabs)	225	9.783
6	Reinforced Concrete	200	0.108
7	Inside Surface Film Resistance for Flat Roofs	5	0.162
8	Light Weight Concrete (Light Weight Aggregate)	15	0.018
	TOTAL THICKNESS =	485	10.187
		U - VALUE (MINIMUM)	0.10 W-m2/K

IMAGE

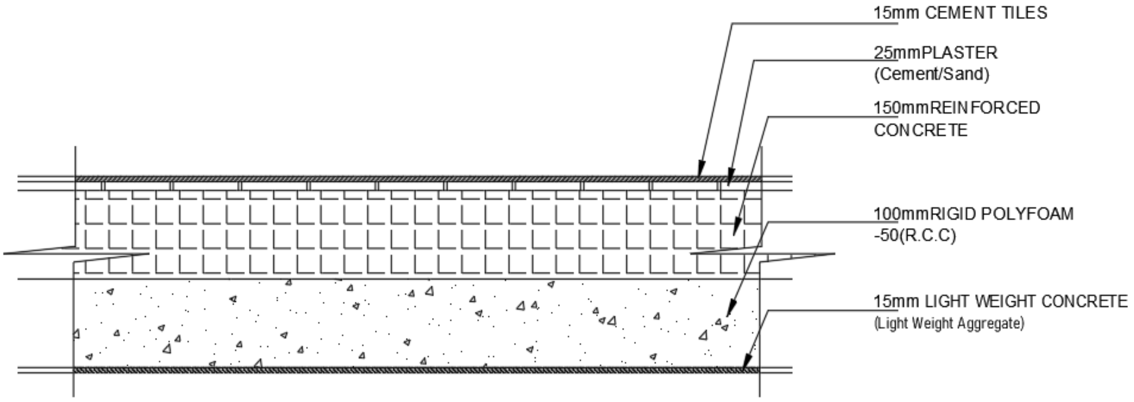


MAT -CV -003

INSULATED GROUND FLOOR COMPOSITION

DATASHEET NO:	MAT-CV-003		
MATERIAL TYPE	INSULATED GROUND FLOOR		
SPECIFICATIONS			
SN	Compositions	Thickness(mm)	Resistance (m2-K/W)
1	Cement Tiles	15	0.014
2	Plaster (Cement / Sand)	25	0.035
4	Reinforced Concrete	250	0.135
5	Rigid Polyfoam-50 ((Rcc)	250	10.87
6	Light Weight Concrete (Light Weight Aggregate)	15	0.018
	TOTAL THICKNESS=	555	11.072
	U - VALUE (MINIMUM)		0.09 W-m2/K

IMAGE



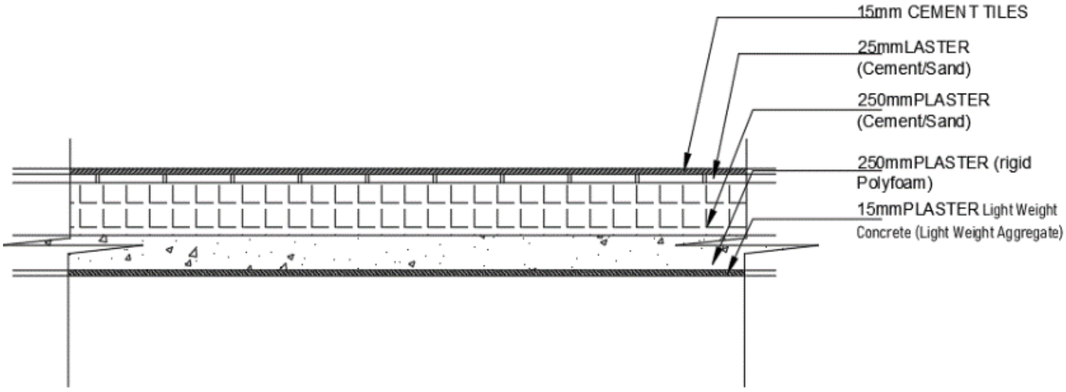
INSULATED GROUND FLOOR

MAT -CV -004

INSULATED GROUND FLOOR COMPOSITION

DATASHEET NO:	MAT-CV-004		
MATERIAL TYPE	TYPICAL FLOOR SLAB COMPOSITION		
SPECIFICATIONS			
SN	**Compositions**	**Thickness(mm)**	**Resistance (m2-K/W)**
1	Cement Tiles	15	0.014
2	Plaster (Cement / Sand)	25	0.035
4	Reinforced Concrete	150	0.081
5	Rigid Polyfoam-50 ((Rcc Roof Slabs)	100	4.348
6	Light Weight Concrete (Light Weight Aggregate)	15	0.018
	TOTAL THICKNESS=	305	4.496
	U - VALUE (MINIMUM)		**0.22 W/m2K**

IMAGE



TYPICAL FLOOR SLAB COMPOSITION

MAT -CV -005

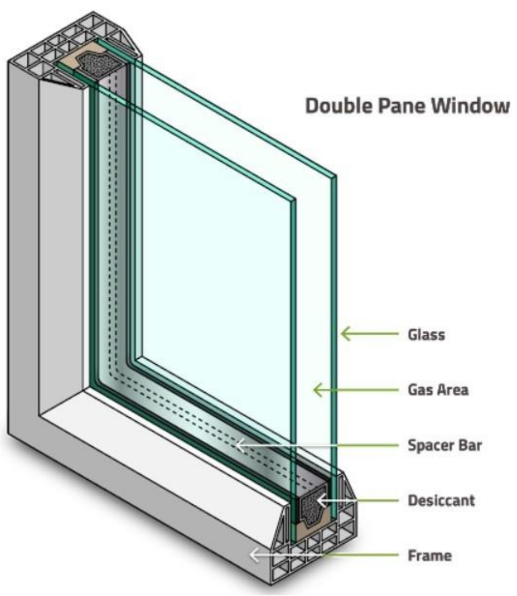
WINDOW / GLAZING DOUBLE LAYER

DATASHEET NO:	MAT-CV-005		
MATERIAL TYPE	WINDOW		
SPECIFICATIONS	DOUBLE LAYER GLASS		

SN	Compositions	OUTER PANE	INNER PANE
1	THICKNESS(mm)	8	8
2	Emmissivity front		0.837
3	Emmissivity back	0.075	0.075
4	Laminated glass	Laminated	Laminated
5	Glass 1 thickness(mm)	3	3
6	Interlayer thickness (mm)	2	2
7	Glass 2 thickness(mm)	3	3

	GAP PROPERTIES
Gas Type	Argon
Argon concentration %	95
Thickness(mm)	30
U - VALUE (MINIMUM)	1.09 W/m2K

IMAGE



MAT -CV -006

REVOLVING DOOR GLAZING / GLASS DATASHEET

DATASHEET NO:	MAT-CV-006			
MATERIAL TYPE	REVOLVING DOOR GLASS			
SPECIFICATIONS				

SN	Compositions	Glass Wall	Glass Door Leaves	Glass Ceiling
1	THICKNESS(mm)	8	15	8
2	Emmissivity front	0.1	0.1	0.1
3	Solar Energy Transmittance	0.5	0.5	0.5
4	Solar Energy Reflectance Front	0.5	0.5	0.5
	Laminated	No	Yes	No
5	Glass 1 thickness(mm)		6	
6	Interlayer thickness (mm)		3	
7	Glass 2 thickness(mm)		6	
	U - VALUE (MINIMUM)	3.40 W/m2K	3.21 W/m2K	3.40 W/m2K

IMAGE