SECTION 23 00 00 - HVAC GENERAL

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. Refer to Division 1 - General Requirements and any and all Supplementary or Special Requirements, all of which apply to work described in Division 23 - HVAC as if written in full herein.

B. The scope of work described in these Specifications and/or indicated on the Drawings shall include the furnishing of all materials, equipment, appurtenances, accessories, connections, labor, etc. required and/or necessary to completely install, clean, inspect, adjust, test, balance and leave in safe and proper operating condition all HVAC systems. All HVAC work shall be accomplished by workmen skilled in the various trades involved.

C. The Drawings and Specifications are complementary to each other and what is called for by one shall be as binding as if called for by both. If a discrepancy exists between the Drawings and Specifications, the higher implied cost shall be included in the bid, and the Architect shall be notified of the discrepancy in writing.

D. All work performed under this specification shall be accomplished in accordance with the requirements and provisions of the following sections:

1.02 CODES AND STANDARDS

A. All HVAC work shall conform to all ordinances and regulations of the City, County and State where the work will take place, including the requirements of all authorities having jurisdiction. The following codes, standards and references shall be observed as a minimum:

1. 2020 Florida Building Codes

2. State Amendments to the Code

3. National Fire Protection Association (NFPA) Standards and Guidelines

4. Local and State Fire Marshal requirements

5. Local Building and Inspection Department requirements

6. Local adopted codes, standards, ordinances (including noise ordinances), or amendments

7. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE)

    a. Standard 90.12019 – Energy Standard for Buildings Except Low-Rise Residential Buildings

b. Standard 90.2-2018 Energy-Efficient Design of Low-Rise Buildings

c. Standard 62.12019 – Ventilation for Acceptable Indoor Air Quality

d. Standard 62.2-2019 – Ventilation and Acceptable Indoor Air Quality in Residential Buildings

e. Standard 55 2020 – Thermal Environmental Conditions for Human Occupancy

f. Other Standards and Guidelines as applicable

8. Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA) Manuals

9. Air Conditioning, Heating, and Refrigeration Institute (AHRI)

10. Air Conditioning Contractors of America (ACCA)

11. American Society of Mechanical Engineers (ASME)

12. Underwriters Laboratories Inc. (UL)

13. Americans with Disabilities Act (ADA)

B. If Code or other requirements exceed the provisions shown on the Contract Documents, the Engineer shall be notified in writing. Where requirements of the Contract Documents exceed Code requirements, work shall be furnished and installed in accordance with the Contract Documents. Any work done contrary to these requirements shall be removed and replaced at the Contractor's expense.

1.03 NOISE CRITERIA DESIGN GOALS

A. Mechanical equipment, air distribution systems and devices shall be designed to not exceed the following noise criteria (NC) levels:

1. Public Space Areas: NC <35

2. Utility/All Other Areas: NC <40

1.04 MISCELLANEOUS DEFINITIONS

A. Terms: The following definitions of terms supplement those of the Division 01- General Requirements and are applicable to Division 23 – Heating, Ventilation, and Air Conditioning (HVAC):

1. Contractor: As used herein the term shall mean "the person or entity referred to throughout the Contract Documents as if singular in number. The Contractor shall designate in writing a representative who shall have express authority to bind the

Contractor with respect to all matters under this Contract. The term "Contractor" means the Contractor or the Contractor's authorized representative."

2. Furnish: As used herein shall mean "supply and deliver to Project site, unload and inspect for damage."

3. Install: As used herein the term shall mean "to place in position for service, temporarily store, unpack, assemble, erect, apply, place, protect, clean, start up, and make ready for use."

4. Owner: As used herein the term shall mean "the person or entity identified as such and is referred to throughout the Contract Documents as if singular in number. The Owner shall designate in writing a representative who shall have express authority to bind the Owner with respect to all matters requiring the Owner's approval or authorization. The term "Owner" means the Owner or the Owner's authorized representative."

5. Product: As used herein shall include materials, systems, and/or equipment, machinery, components, and fixtures forming the work result. Not materials or equipment used for preparation, fabrication, conveying, or erection and not incorporated into the work result. Products may be new, never before used, or re-used materials or equipment.

6. Provide: As used herein shall mean "furnish and install, complete and ready for the intended use."

7. The Work: As used herein the term shall mean "the construction and services required by the Contract Documents, whether completed or partially completed, and includes all other labor, materials, equipment, and services provided or to be provided by the Contractor to fulfill the Contractor's obligations. The Work may constitute the whole or a part of the Project.

8. Experienced: When used with an entity or individual, "experienced" means having successfully completed a minimum of five previous projects similar in nature, size, and extent to this Project; being familiar with special requirements indicated; and having complied with requirements of authorities having jurisdiction.

1.05 WORK INCLUDED

The HVAC Systems installed and work performed under this Division of the Specifications shall include, but not necessarily be limited to:

A. Airside Systems

1. Equipment: including fans, unitary air conditioners, air handling units, fan-coil units, make-up air units, dedicated outdoor air units, furnaces, split systems, etc.

2. Ductwork and Accessories: including sheet metal, duct-board, kitchen hood and dishwasher exhausts, flexible ductwork, fire and smoke dampers, access doors, etc.

3. Air Terminal Devices: including powered induction units, variable air volume valves, etc.

4. Air Distribution Devices: including louvers, registers, grilles, diffusers, etc.

B. Refrigerant and Water Systems

1. Equipment: including pumps, air separators, expansion tanks, water chillers, cooling towers, filtration systems, chemical treatment, heat exchangers, boilers and space heating water heaters, feed-water systems, condensing units, etc.

2. Piping, Tubing and Accessories: including pipe, refrigerant tubing, valves, solenoids, thermal expansion valves, strainers, air vents, pipe and equipment drains, condensate drains, expansion devices, etc.

C. Equipment, Ductwork and Piping Supports

1. Equipment Mounts: including roof curbs, concrete housekeeping pads, equipment rails, miscellaneous steel, etc.

2. Hangers and Support Devices: including inserts, hanger rods, strut channel, cross-bracing, anchor bolts, pipe anchors, restraints, etc.

3. Vibration Isolation and seismic restraint: including inertia bases, flexible couplings, expansion devices, snubbers, springs, waffle pads, seismic restraints, etc.

D. Insulation

1. Ductwork Insulation: including exterior duct wrap, internal duct liner, fire wrap, etc.

2. Piping and Equipment Insulation: including preformed, board and wrap.

E. Miscellaneous HVAC Equipment: electric heaters, roof hoods, heat tracing, etc.

F. Automatic Temperature Controls

1. Building Automation System (BAS)/Facility Management System (FMS): same as above but networked to a central human-machine computer interface, including all software and programming, display graphics, etc.

G. Labor and Equipment: including project management, supervision, tradesmen, lifts, fork-trucks, cranes, scaffolding, saws, wrenches, etc.

H. Equipment and Valve Identification

I. Start-up and Commissioning

J. Demonstration and Owner Training

K. Testing, Adjusting and Balancing

1.06 ENGINEER'S DRAWINGS

A. The locations, arrangement and extent of equipment, devices, ductwork, piping, and other appurtenances related to the installation of the HVAC work shown on the Drawings are approximate and define the intent of the design. The Contractor shall not scale Engineer's Drawings, but shall refer to the architectural drawings for exact dimensions of building components. Should a conflict exist between the architectural and engineering drawings regarding dimensions and scale, the Contractor shall notify the Architect of the discrepancy.

B. Materials, equipment or labor not indicated but which can be reasonably inferred to be necessary for a complete installation shall be provided. Drawings and Specifications do not undertake to indicate every item of material, equipment, or labor required to produce a complete and properly operating installation.

1.07 EQUIPMENT, MATERIALS AND BID BASIS

A. Manufacturers' names, model numbers, etc. cited on the Drawings and in the Specifications are for the purpose of describing type, capacity, function and quality of equipment and materials required. All project design and coordination between disciplines has been performed as if the named manufacturer and specific piece of equipment will be provided to the project by the Contractor.

B. Alternate equipment and/or materials other than that named on the Drawings and in the Specifications may be proposed for use, but all equipment and materials shall conform entirely to the specified base items. Proposed alternate equipment shall be substantially equal in size, weight, construction and capacity. Alternate equipment and materials shall be submitted only as full equivalent to the equipment and materials specified, with sufficient supportive documentation and technical literature to demonstrate quality, performance, and workmanship without doubt or question. Requests for prior approval of alternate products shall be made at least ten (10) days prior to the bid date and as required by Division 1 - General Requirements. The Engineer shall consider the use of the alternate equipment based on the supportive documentation made available to him, and shall approve or disapprove any proposed alternates. Major exceptions to these specifications will be considered sufficient cause for rejection of the submittal. The decision of the Engineer shall, in all cases, be final.

1. The ten (10) day prior approval submittal shall include a Compliance Review of the Specifications and Addenda (if any). The Compliance Review shall be paragraph-by-paragraph review of the Specifications with the following information; "C", "D" or "E" marked in the margin of the original Specifications and any subsequent Addenda.

2. "C": Comply with no exceptions.

3. "D": Comply with no deviations. For each and every deviation, provide a numbered footnote with reasons for the proposed deviation and how the intent of the Specification can be satisfied.

4. "E": Exception, does not comply. For each and every exception, provide a numbered footnote with reasons and possible alternatives.

5. Manufacturer shall provide complete paragraph-by-paragraph compliance document detailing unit conformance to the specification. The Engineer will not review the proposal for equipment compliance.

Unless a deviation or exception is specifically noted in the Compliance Review, it is assumed that the bidder is in complete compliance with the plans and specifications. Deviations or exceptions taken in cover letters, subsidiary documents, by omission or by contradiction do not release the bidder from being in complete compliance, unless the exception or deviation has been specifically noted in the Compliance Review. The bidder may submit the latest state-of-the-art components in lieu of specified components at no additional cost, where latest state-of-the-art components perform better than what is specified. All deviations from the specifications must be approved by the Architect/Engineer and the Owner.

C. The Contractor shall coordinate the installation of all HVAC equipment proposed for use in this project with all building trades (architectural, structural, electrical, etc.). Coordination shall be accomplished prior to, and shall be reflected in, the equipment submittals for approval. When the Contractor requests substitution of alternate equipment, it is with the knowledge that he shall be responsible for any and all costs required by the substitution, including necessary engineering and construction revisions in his or any other contract or trade to satisfy the design intent shown on the Plans and described in the Specifications.

D. All materials exposed within HVAC plenums shall have a flame-spread index of not more than 25 and a smoke-developed rating index of not more than 50 unless otherwise allowed by code.

1.08 SUBMITTALS

A. The Contractor shall prepare, submit and obtain Engineer's review of all manufacturers' data on the HVAC equipment and systems prior to ordering, purchasing or installing any equipment or materials. Shop drawings shall be submitted electronically in a portable document format (pdf). An acceptable alternate would be to submit six (6) hard copies of the complete submittal, five of which will be reviewed and returned. Submittals shall be as described in Division 01 - General Requirements. Prior to submitting to the engineer, the contractor shall review and subsequently place his approval stamp on the shop drawings indicating conformance with the contract documents. Submittals shall be transmitted simultaneously in a single .zip file or, in the case of hard copies, three-ring ring binders with the associated specification sections cited and the items submitted clearly identified. The engineer will review the submittals one time for conformance with the contract documents and return them with their approval stamp indicating "Reviewed", Reviewed as Noted", "Returned for Corrections-Resubmit", "Rejected, See Comments" or "Reviewed for Coordination Only". For submittals requiring a resubmittal, one additional review will be performed at no charge. Subsequent re-reviews will be made after the engineer notifies the Architect/Owner that an hourly charge will occur for time expended performing the re-review. Submittals lacking the contractor's approval stamp and partial submittals will be returned without review. Submittals, as a minimum, shall include:

1. All HVAC items scheduled on the Drawings

2. Equipment arrangement, ductwork and piping drawings. Contractor drawings shall be prepared at a minimum scale of 1/8" = 1'-0". A scale of 1/4" = 1'-0" scale is preferred. Drawings shall be indicative of actual equipment purchased and shall show all offsets, transitions, fittings, dampers, valves, hanger locations, etc. Sections are required in spatially tight areas (e.g. kitchens, laundries, central plants, mechanical rooms, etc.) The following will guide the Contractor as to minimum drawing detail required:

    a. Clearly indicate top and bottom of duct and pipe elevations. All elevations shall be coordinated as to not conflict with structural, plumbing, electrical and architectural trades.

    b. Indicate all offsets (both vertical and horizontal).

    c. Indicate graphically all duct and pipe joints and their lengths.

    d. Submit duct and pipe-work fabrication schedule indicating duct size range with minimum duct material gauges, pipe schedule being used, duct and pipe connection joint types, section lengths, duct reinforcement type and spacing, etc.

    e. Indicate graphically all ductwork to be fabricated with internal duct liner.

    f. Indicate all insulation for ductwork and piping.

    g. Indicate all dampers and valves as shown on design documents and called for in the specifications.

    h. Indicate all flexible connectors where required by specifications and notes.

3. Flexible ductwork, duct-board, insulation and linings

4. Ventilation controllers, dampers, louvers, air distribution devices, wall terminations (wall caps), roof terminations (roof caps, hoods, jacks, etc.)

5. Manufacturer’s cut sheets of all piping and tubing materials

6. Where split systems are used in a “long line application,” submit manufacturer’s refrigerant line set routing drawings and engineered calculations supporting installed line lengths and recommended suction and liquid line sizes (deviations in the installed lengths and sizes shall be recorded on the as-built drawings and coordinated with the manufacturer to reconfirm that long line guidelines are being met).

    a. Identify and provide cut sheets of any and all accessories required to make the system complete, functional and reliable.

b. Any split system with 75 feet of separation between the outdoor unit and the indoor unit requires that the contractor obtain a warranty approval letter from the equipment manufacturer certifying the long line length distances shown on the submitted shop drawings are acceptable.

c. Refer to the EQUIPMENT INSTALLATION - COMMON REQUIREMENTS paragraph below.

7. Refrigerant type and charge (lbs.) for each item of equipment utilizing refrigerant.

8. AHRI Certificates

9. Valves, thermometers, pressure gauges

10. Thermal expansion/contraction piping system design including complete layout drawings indicating anchor loads, points, and method of structural support.

11. Roof curbs, equipment supports, hanger systems, vibration isolators, seismic restraints

12. Control equipment, systems and diagrams

13. Test and balance reports

B. All submittal approvals required by any code or enforcement authority, insurance underwriter, etc. shall be obtained prior to being submitted to the Engineer.

C. Review of submittals by the Engineer does not relieve the Contractor from responsibility for complying with all requirements of the Contract Documents. Furthermore, it shall be the responsibility of the Contractor to coordinate the requirements (roof penetrations, wall penetrations, floor penetrations, curbs, electrical, etc.) of all approved equipment with the other trades and disciplines.

D. All submittals shall be identified by the equipment mark or tag identification numbers shown on the Contract Drawings. Each individual submittal item shall be marked to show which specification section pertains to the item.

E. The Contractor shall provide a written statement confirming coordination of voltage requirements for all HVAC equipment requiring an electrical connection. Statement shall bear the names and signatures of the HVAC and electrical contractors. A photocopied reproduction of the below statement is acceptable.

VOLTAGE COORDINATION STATEMENT

This statement is to confirm that the voltages of the equipment provided under this specification have been coordinated with the Electrical Drawings, as well as with the Electrical Contractor.

HVAC Contractor:

Project Manager Name:

Project Manager Signature/Date:

Electrical Contractor:

Project Manager Name:

Project Manager Signature/Date:

1.09 PERMITS

A. The Contractor shall obtain all permits and inspections required for the installation of the HVAC work and pay all charges incident thereto. He shall deliver copies of all certificates of permit and inspection to the Architect.

1.10 COORDINATION OF TRADES

A. The Contractor shall give full cooperation to other trades, and shall furnish all information necessary to permit the work of all trades to be installed satisfactorily and with the least possible interference or delay.

B. Piping and other HVAC equipment shall not be installed without first coordinating the installation of same with other trades. The Contractor, at his own expense, shall relocate all uncoordinated ductwork, piping and other HVAC equipment installed should they interfere with the proper installation and mounting of electrical, plumbing equipment, ceilings and other architectural or structural finishes.

C. The Contractor shall coordinate the elevations of all ductwork, piping and equipment above ceilings and in exposed areas with the work of all other disciplines prior to installation.

D. In areas where more than one trade is required to use common openings in beams, joists, chases, shafts and sleeves for the passage of conduits, raceways, piping, ductwork and other materials, the Contractor must coordinate the positions of all piping and equipment to be furnished under this section so that all items including the materials and equipment of other trades may be accommodated within the space available.

E. The HVAC Contractor shall confirm that his work does not interfere with the clearances required for finished columns, pilasters, partitions, walls or other architectural or structural elements as shown on the Contract Documents.

F. Work that is installed under this Contract which interferes with the architectural design or building structure shall be removed and relocated as required at no additional cost to the Contract.

G. Coordinate power and fire alarm requirements of all combination fire/smoke dampers and smoke dampers with the electrical contractor.

H. The General Contractor shall coordinate service access paths for roof-mounted equipment requiring routine maintenance. Provide code compliant galvanized steel crossing structure (e.g. stairs with handrails, ladders, etc.) for any obstruction (ductwork, piping, etc.) that exceeds 1'-6" in height x 1'-6" in width. In addition, refer to Part 3 below - EQUIPMENT INSTALLATION - COMMON REQUIREMENTS. Details of such crossings shall be included with piping and ductwork layout and coordination drawings.

I. Coordinate with the roof system used so that a minimum of 8" of the roof curb is above the finished roof for flashing purposes. The top of the curb shall be level and the slope of the roof shall be compensated for by the curb.

J. Roof curbs for equipment located in seismic or high wind areas will require the design (including attachments to the roof and equipment) to be certified by a licensed structural engineer.

1.11 OPERATION AND MAINTENANCE MANUALS

A. The Contractor shall prepare a minimum of two (2) instruction manuals, one of which shall be submitted to the Architect for the Engineer's review. Manuals shall describe installation, operation and maintenance of all HVAC equipment and shall include copies of control schematics, sequences of operation, function and operations of all components, as well as the Contractor's name, address, and telephone number. Manuals shall also contain one copy of all manufacturers' drawings, pamphlets, data, parts lists, and instruction manual for each piece of equipment. Upon approval, one copy shall be delivered to the Owner; one copy shall be kept by the Contractor. The pamphlets and drawings are to be neatly bound in (a) 3-ring binder(s). In addition to the hard copy, provide electronic files (PDF format) of the manuals.

1.12 AS-BUILT DRAWINGS

A. The Contractor shall maintain a record of all changes in the work from that shown in the Contract Documents. The record shall be by red-line mark-up on the most current set of Engineer's Drawings kept in the field office. After all work is completed, the Contractor shall prepare a set of "as-built" reproducible drawings of similar type and quality as the Engineer's Drawings. As an alternate to hard copy drawings, provide electronic files (PDF format) of the as-built conditions. As-built drawings shall accurately depict actual final arrangement of all HVAC items. As-built drawings shall be delivered to the Architect.

1.13 WARRANTY

A. All equipment furnished and installed under this Contract shall be provided with the manufacturer's standard warranty unless otherwise noted.

B. All reciprocating, rotary and scroll air conditioning compressors shall be provided with an extended 5-year parts warranty.

C. The Contractor shall make good all defects in material, equipment, or workmanship disclosed within a period of one (1) year from date of building acceptance by the Owner. The phrase "make good" shall mean to furnish promptly, without charge, all work necessary to remedy the defects to the satisfaction of the Engineer.

1.14 COMMISSIONING

A. This project requires commissioning per the requirements of the (city, code, and/or specific energy program). Commissioning shall be by applicable contractor and either the engineering firm of record or a 3rd party commissioning agent. Refer to the commissioning (specifications, plan, checklists, and/or additional on drawing notes) for additional information.

PART 2 - PRODUCTS

2.01 GENERAL

A. All equipment, materials, accessories, etc. used shall be new and of current production unless specified otherwise. Equipment not specified in the Engineer's Drawings shall be suitable for the intended use and shall be subject to approval by the Engineer.

B. All equipment, products and materials shall be free of defects and shall be constructed to operate in a safe manner without excessive noise, vibration, leakage, or wear.

C. All equipment shall bear the inspection Label of Underwriters Laboratories Inc.

D. All equipment and material for similar applications or systems shall be provided from the same manufacturer unless noted otherwise.

E. The VOC content of all products in this section shall not exceed the VOC limits established in Section 01 81 13 Sustainable Design Requirements.

F. VOC Content: Submit adhesive and sealants product information or MSDS showing VOC Content information for all applicable products specified under this section. All applicable products in this section must meet low VOC content as specified by LEED Specification Section 01 81 13 Sustainable Design Requirements.

2.02 ELECTRICAL WORK

A. Except as otherwise specified or noted, electrical equipment used for HVAC systems shall be as specified herein.

B. Motor controls, system controls, starters, disconnects, pilot lights, push buttons, etc. shall be furnished by the HVAC Contractor compatible with the apparatus that it operates. Electrical equipment shall be wired for the voltage shown on the Electrical Drawings.

C. The Contractor shall be responsible for coordinating and furnishing equipment of voltage shown on the electrical documents.

D. Electric motors shall be NEMA Premium Efficiency open drip proof type. Motors shall meet NEMA MG1 Tables 12-11 and 12-12 of EISA, 2021. Motors shall be selected with a minimum of 15% safety factor greater than the fan brake/horsepower (e.g. 4.75 BHP would require a nominal 7½ HP motor). The motor service factor shall not be used as part of the safety factor. All motors shall have thermal overload protection. Motors shall be capable of operating at + 10% of the design voltage without voiding the manufacturer's

warranty. Motors that drive equipment that will run continuously shall be IEC 60034-1 continuous duty rated.

E. Motors controlled by a variable frequency drive (VFD) shall be inverter duty motors designed according to the requirements of NEMA MG 1, Part 31, "Definite Purpose, Inverter Fed Motors" and shall be compatible with the particular manufacturer's drive that is used.

1. Shaft Grounding Rings - All motors controlled by variable frequency drives shall be equipped with a maintenance free, conductive micro fiber, shaft grounding ring with a minimum of two rows of circumferential micro fibers to discharge damaging shaft voltages away from the bearings to ground.

a. Motors up to 100HP shall be provided with one shaft grounding ring installed either on the drive end or non-drive end. Motors over 100HP shall be provided with an insulated bearing on the non-drive end and a shaft grounding ring on the drive end of the motor. Grounding rings shall be provided and installed by the motor manufacturer or contractor and shall be installed in accordance with the manufacturer's recommendations.

b. Shaft grounding rings shall be AEGIS bearing protection ring by Electro Static Technology-ITW or approved equal.

2. High Frequency Grounding Straps - All motors controlled by variable frequency drives shall be bonded from the motor foot to the system ground with a high frequency ground strap fabricated of flat braided, tinned copper with terminations to accommodate motor foot and system ground connection.

a. Proper grounding of motor frame for all inverter-driven induction motors shall be in accordance with ABB Technical Guide No. 5 and Allen Bradley Publication 1770-4.1 Application Data Industrial Automation Wiring and Grounding Guidelines

b. High frequency bonding strap shall be AEGIS high frequency ground strap by Electro Static Technology-ITW or approved equal.

F. Starters for motors ⅓ HP and smaller shall be manual type, and for ½ HP and larger, shall be magnetic type. Starters shall be minimum size 0, combination type (with disconnect and lockable handle) with molded case circuit breaker. Starters for motors with remote or automatic control shall be magnetic. Relays, interlocks and auxiliary contacts shall be provided as specified and required.

G. Magnetic motor starters shall be across-the-line, full voltage, non-reversing type unless otherwise indicated on the Drawings or specified herein. Starters for motors 75 HP and greater shall be solid state, reduced voltage type.

H. Motor controls shall be either "Hand-Off-Auto" switches or "On-Off" push buttons with one indicating light. "Hand-Off-Auto" switches shall be provided for automatically controlled apparatus.

I. Motor starters that are not an integral part of HVAC equipment shall be installed in conformance with Division 26 - Electrical Requirements.

J. All “loose” disconnects and starters shall be installed by Division 26.

K. Power wiring to disconnects, starters, and equipment shall be provided and installed by Division 26. All equipment requiring electrical power shall be provided with a disconnect switch at each piece of equipment. Coordinate switch type (fused or non-fused) with equipment characteristics, manufacturer’s recommendations and the electrical drawings.

L. Provide all system controls and associated control and interlock wiring for complete and operable systems. 120 volt and higher wiring shall be MC cable or in conduit in accordance with local codes and the materials and installation requirements of Division 26 - Electrical.

M. Coordinate power and fire alarm requirements of all combination fire/smoke dampers and smoke dampers with the electrical contractor.

N. All starters and variable frequency drives shall be labeled on the face of the device with a semi-rigid plastic laminate nameplate with 1" high white letters on a black background securely affixed to the equipment. The label shall indicate equipment served (equipment tag used on the Drawings). Labels shall be furnished and installed by the Contractor.

O. All starters for 3-phase equipment shall have overload devices in each phase.

P. Wiring diagrams shall be furnished by the Contractor.

Q. Coordinate with the electrical drawings for the calculated available fault current at the panelboard serving multi-motor and combination-load equipment or the calculated available fault current indicated at the equipment. This fault current value shall be utilized to determine the correct Short Circuit Current Rating (SCCR) for the equipment. The equipment nameplate shall bear a rating of no less than the panelboard rating or the calculated fault current.

R. Acceptable manufacturers shall be General Electric, Square D, Eaton, Siemens and Allen Bradley.

2.03 AIR FILTERS

A. All filters shall be U.L. 900 classified.

B. Filters shall be pleated disposable type (MERV 6 minimum) unless specified otherwise.

C. Install one set of new filters in air handling equipment during construction and install a new set prior to test and balance. Fan powered induction units shall have a temporary roll filter media installed at the plenum air inlet during construction. Remove temporary filter media prior to test and balance. Clean and vacuum all inlets prior to test and balance.

D. Temporary roll filter media shall be provided at the inlets to all air handling equipment operated during construction. Remove temporary filter media prior to test and balance. Clean and vacuum all inlets prior to test and balance.

2.04 HVAC WATER SYSTEMS BREACH CONTROL

A. Any HVAC system requiring a make-up water connection shall be provided with an automatic breach containment valve as manufactured by Cla-Val. The valve shall detect a breach downstream, via differential pressure, and close to reduce the potential of catastrophic water damage to the building and furnishes.

PART 3 - EXECUTION

3.01 GENERAL

A. All equipment and materials shall be completely installed, adjusted, and fully operational with all accessories and connections.

B. Equipment, piping, ductwork, etc. shall fit into the spaces provided in the building and shall be installed at such time and in such a manner as to avoid damage and as required by the job progress. In general, ductwork, piping, equipment, etc. shall be installed tight to structure above. The Contractor shall coordinate work with other trades and locate work described herein to avoid interferences with structural, electrical and architectural work. Shop drawings shall clearly indicate any conflicts with other trades. Equipment, accessories and similar items requiring normal servicing or maintenance shall be accessible.

C. The Engineer reserves the right to direct the removal of any item which, in his opinion, does not present an orderly and reasonably neat or workmanlike appearance. Such removal and replacement shall be done when directed by the Engineer and without additional cost to the Owner.

D. Listed mounting heights are to the finished bottom of the device unless otherwise noted.

E. All work shall be designed and installed to comply with the requirements for the seismic design category and use group for the area in which the building is constructed.

F. Expansion in piping systems shall be compensated for using u-bends, z-bends or expansion joints as indicated. U-bends (loops) and z-bends shall be complete with pipe guides and anchors. Expansion compensation in piping risers over 100 feet in length shall be made with engineered systems; either spring type isolators and central anchor system (by Mason Industries) or flexible hose expansion loops (Metraloop as manufactured by the Metraflex Company). Refer to specification Section 23 21 13 for additional requirements.

3.02 STORAGE AND PROTECTION OF STORED MATERIALS

A. During construction, all equipment shall be properly protected against damage, defacing and freezing with shipping cartons, plastic sheeting, shipping covers, etc.

B. All open ends of piping and equipment shall be sealed with nipples and caps, plugs, and test plugs until final connection to system is made.

C. All equipment, piping and ductwork shall be protected to prevent entrance of foreign matter and debris by covering exposed openings during construction.

D. Handle and store materials in accordance with manufacturer's and supplier's recommendations and in a manner to prevent damage to materials during storage and handling. Replace damaged materials.

E. Equipment and materials shall not be installed until such time as the environmental conditions of the job site are suitable to protect the equipment or materials. Equipment or materials damaged, or which are subjected to these elements, are unacceptable and shall be removed from the premises and replaced.

3.03 PROTECTION OF HVAC SYSTEMS IN OCCUPIED BUILDINGS

A. Protect equipment and air distribution systems as outlined in SMACNA's IAQ Guidelines for Occupied Buildings Under Construction, latest edition.

3.04 BUILDING DRY-OUT DURING CONSTRUCTION

A. HVAC equipment shall not be used to dehumidify the building interior and dry-out construction materials. The HVAC system does not have the capacity to perform a building dry-out. The HVAC equipment shall not be operated until the building is completely dried-in and construction is substantially complete.

B. Coordinate with the general contractor to provide industrial grade desiccant type dehumidifiers to perform building dry-out. Propane or diesel space heaters are not acceptable as the combustion process adds moisture to the air.

3.05 CUTTING, PATCHING, AND SEALING

A. The work shall include all cutting and patching required as part of the HVAC installation. Refer to Division 1 - General Requirements.

B. All penetrations in walls, ceilings, and partitions required by mechanical work shall be sealed with an appropriate pliable sealant or fire caulking to make the penetration airtight. Penetrating items shall include, but not be limited to, ductwork, piping, conduit, cables, control wiring (especially for thermostats and sensors), hangers, mounting hardware, etc.

3.06 CONCRETE WORK

A. Construct curbs, pads and similar supports for equipment where required.

B. Provide 4" (min.) thick housekeeping pads for all floor mounted equipment, extending 6" beyond the area occupied by the equipment. Dowel pads to structural slab.

C. Perform concrete work in accordance with applicable portions of Division 3 - Concrete. Minimum compressive strength of concrete shall be same as specified for slabs on grade.

D. Mix and install grout for HVAC equipment base bearing surfaces and anchors. Provide forms as necessary and place grout to completely fill equipment bases.

3.07 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

A. Install equipment to allow maximum possible headroom unless specific mounting heights are indicated.

B. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.

C. Install HVAC equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.

D. Install equipment to allow right-of-way for piping to be installed with the required slope.

E. For roof and attic mounted equipment requiring routine maintenance, allow for an unobstructed path from the roof/attic service entry point to the equipment. The path area shall be a minimum of 6'-0" high by 3'-0" wide.

F. Split system outdoor unit equipment has been shown indicating matched systems of the indoor unit with its associated outdoor unit. While the location of the outdoor units are approximate, the importance of unit locations relative to the refrigerant line set penetration through a wall or roof is critical for the project. Prior to ordering equipment, the contractor shall carefully coordinate the line set routing and requirements with the split system manufacturer to insure installation guidelines, especially for long line applications, are being followed. Refrigerant line sets shall be routed to reduce the system total equivalent length and minimize system capacity losses due to elbows, fittings, valves, etc. After the coordinated routing drawings have been approved and certified by the split system manufacturer, they shall be submitted for review along with the equipment and any required accessories. During installation, the contractor is responsible for keeping as-built refrigerant piping installation drawings noting any deviations to the proposed routing. Deviations that may affect proper system operation or performance shall be reviewed by the manufacturer immediately and corrective action implemented as required.

3.08 EQUIPMENT SUPPORTS

A. Major equipment supports (structural steel frames, framed structural slab and wall openings, etc.) shall be furnished and installed by others; however, the HVAC work shall include furnishing and installation of all miscellaneous equipment supports, structural members, rods, clamps and hangers required to provide adequate support of all HVAC equipment.

B. Unless otherwise shown on the Drawings, all HVAC equipment, piping, and accessories shall be installed level, square, and plumb.

C. All equipment, piping, etc. supported by structural bar joists shall be supported only by the top chord of the joists. Hangers shall not be attached to the bottom chord of any joists.

3.09 PIPE AND DUCTWORK PENETRATIONS

A. Sleeves shall be installed in all masonry or concrete walls, floors, roofs, etc. for pipe and ductwork penetrations. Sleeves for pipe shall be schedule 40 black steel pipe. Sleeves for ductwork shall be 20-gauge galvanized steel. Ductwork sleeves shall be sized to provide

a minimum of ¼" clearance between the sleeve and duct. For insulated ducts, the clearance shall be between the sleeve and the insulation.

B. As far as possible, all pipe and ductwork penetrations shall be provided for at the time of masonry or concrete construction. Where drilling is required, only core drills shall be used. Star drills shall not be used.

C. Piping entering the building below grade and passing through cast-in-place concrete walls or floors shall be fitted with a mechanical rubber seal inside of a 12" long schedule 40 steel pipe sleeve with integral water-stop. The sleeve shall be sized to house the mechanical rubber seal and carrier pipe. The mechanical rubber seal shall be constructed of EPDM and stainless-steel hardware and provide a hydrostatic seal of up to 20 psi and up to 40 feet of head. Products shall be Metraseal as manufactured by The Metraflex Company or equal by Link-Seal.

D. All pipes passing through masonry walls shall be fitted with schedule 40 steel pipe sleeves. Sleeves shall be of the first possible size larger than the outside diameter of the pipe to be sleeved or the insulation jacket on covered pipes. Sleeves shall be flush on either side of the masonry walls.

E. All pipes passing through the masonry floors shall be fitted with schedule 40 steel pipe sleeves of the first size larger than the pipe to be sleeved. All sleeves on these floors shall extend 1" above the finished floor and 1" below the bottom of the slab. All pipe sleeves through the floors of the mechanical room shall be 16-gauge galvanized steel extending 2" above the finished floor. After the pipes are installed, the annular space shall be packed with fiberglass to ½" from the top of the sleeves, and then topped off with a ½" depth of sealant such as PRC-Rubber Caulk 7000 or other such approved sealant.

F. All pipes penetrating walls or floors of any construction shall be installed with escutcheon plates on both sides of the penetration securely fastened to the wall or floor with a clamping device for holding the escutcheon in position.

G. In exposed areas, escutcheon plates shall be chrome plated. All escutcheon plates shall be sized to completely conceal the penetration.

H. Ductwork penetrating walls or floors of any material shall be installed with closure plates on both sides of the penetration.

I. All pipe and duct penetrations of fire, smoke, or fire and smoke-rated assemblies shall be fire-stopped as required to retain the integrity of the UL-rated assembly. Fire barrier products shall be as manufactured by Tremco, Hilti, 3M, Metacaulk, Nelson, STI or approved equal. Refer to Division 7 - Thermal and Moisture Protection.

J. Ensure that materials used for fire-stopping, caulking, sealing, pest/rodent proofing, etc. are compatible with the piping material used. Some materials are known to react with certain piping systems causing premature failure.

3.10 FLASHING

A. All piping and ductwork penetrating roofs shall be flashed in an approved manner, shall be watertight, and shall conform to the requirements detailed in Division 7 - Thermal and Moisture Protection.

3.11 EQUIPMENT LABELING

A. All HVAC equipment shall be labeled. This shall include all central plant, air handling or air conditioning equipment, air terminals, and other similar and miscellaneous equipment.

B. Labels for air terminals or other devices shall be located for optimum visibility through access panel or removed ceiling tiles.

C. Equipment labeling shall be one of the following, unless noted or specified otherwise:

1. Permanently attached plastic laminated signs with engraved 1" high lettering

2. Stencil painted identification, 2" high letters, with standard fiberboard stencils and standard black (or other appropriate color) exterior stencil enamel

D. Labels, stencils, and signs shall be legible, UV resistant and constructed to be long lasting.

3.12 VALVE TAGS

A. Each valve in the HVAC system is to be provided with an individually numbered valve tag.

B. Valve tags are to be brass or plastic laminate, 1½" minimum diameter with brass chain and hook for securing to the valve.

C. Valve tags will include a designation to indicate the appropriate system. Numbering shall be consecutive for each service of the hot, chilled, steam, condensate return, or condenser water systems.

D. A printed list or schematic drawing shall be compiled for each system indicating the location and detailed description of the system or equipment served.

E. One (1) copy of each list shall be framed and mounted at the location designated by the Building Engineer. An additional copy of each list is to be included in the Operations and Maintenance Manual.

3.13 CLEANING

A. At all times, the premises shall be kept reasonably clean and free of undue amounts of waste, trash and debris by periodic cleaning and removal. After completion, all foreign material, trash and other debris shall be removed from the job site.

B. After all equipment has been installed, but prior to testing and balancing, all equipment, piping, ductwork, etc. shall be thoroughly cleaned both inside and out.

C. All water piping shall be chemically flushed and cleaned prior to circulating water through equipment.

D. After cleaning, filters shall be installed where required and all systems shall be tested and balanced.

E. After testing and balancing and just prior to Owner review and acceptance, all systems shall be finally cleaned and left ready for use.

3.14 PAINTING

A. Painting will be done under Division 9 - Painting except as otherwise noted, but the HVAC Contractor shall leave all surfaces of work free of rust, dirt and grease.

B. The HVAC Contractor shall touch-up any equipment scratched in shipment or during installation to match the original finish. Touch-up painting of HVAC equipment shall be part of the HVAC work.

C. Any visible ductwork through grilles, registers and diffusers shall be painted flat black.

D. Provide one coat of rust preventive primer on all new structural steel supports and new ferrous surfaces not galvanized, including insulated and non-insulated HVAC piping. Rust preventive painting shall be part of the HVAC work. Rust preventive paint shall be “Rust Destroyer” by Advanced Protective Products, Inc., Fair Lawn, NJ, (800) RUST-007. Product shall have a 5-year warranty when applied directly over rust. Clean and prepare surface per manufacturer’s recommendations.

E. All painting and coating shall match the original finish and shall conform to the requirements detailed in Division 9 - Finishes.

F. Do not paint over equipment nameplates, nonferrous hardware, accessories or trim.

3.15 PRESSURE TESTING

A. Unless otherwise specified herein, all HVAC piping shall be tested as required by Code to 1½ times the rated system pressure or 100 psig, whichever is greater. Care shall be taken to isolate all equipment not suitable for this test pressure by installing pipe caps or blank flanges at the equipment connections. All valves and fittings shall be tested under pressure.

3.16 PERFORMANCE AND DEMONSTRATION TESTS

A. All testing and demonstration of any and all HVAC systems required for acceptance by any authorities having jurisdiction shall be included as part of the HVAC work. This shall include the furnishing of any and all testing equipment, smoke generation devices, and any other required equipment or accessories, and all necessary labor required to perform any required tests or demonstrations. The Contractor shall coordinate and verify all devices, equipment and sequence of testing and/or events with such authorities having jurisdiction. The Contractor shall perform a minimum of two (2) satisfactory preliminary tests or demonstrations prior to any formal tests and/or demonstrations for any code authorities and

shall give a minimum of five (5) days advance notice to the Engineer of any and all preliminary tests and/or demonstrations, indicating the date and time of such tests.

B. For testing and demonstration of smoke control systems, the requirements in paragraph 3.16.A apply. In addition, coordinate with the owner/operator for witnessing of formal testing.

3.17 TRAINING

A. Upon completion of the work, the Contractor shall conduct operation and training session(s) for the Owner's key operating personnel. These sessions shall be of sufficient length and duration to adequately explain the design intent and proper operating and maintenance techniques for all HVAC equipment and systems. After these sessions are completed, the Contractor shall provide a copy of a signed statement by the Owner that his personnel are thoroughly familiar with and capable of operating all HVAC equipment and systems.

END OF SECTION

SECTION 23 03 00 - ROOF CURBS

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

B. Roof curbs for equipment located in seismic or high wind areas will require the design (including attachments to the roof and equipment) to be certified by a licensed structural engineer.

1.02 WORK INCLUDED

A. Receipt, unloading, handling, proper storage and protection from damage of all materials.

B. Layout and coordination of work with other trades.

C. The work included under this section shall include all labor, materials, accessories, services and equipment necessary to furnish and install curbs complete as indicated on the Drawings and as specified herein.

PART 2 - PRODUCTS

2.01 GENERAL

A. Prefabricated curbs for HVAC equipment located on the roof shall be manufactured by Canfab, Micrometl, Pate, Thycurb, Roof Products & Systems (RPS), Inc., or approved equal.

2.02 ROOF CURBS

A. Curbs shall be RPS Series ARC with integral fiber cant fabricated to match any roof slope and have a minimum height of 24". Coordinate with the roof system used so that a minimum of 14" of the curb is above the finished roof for flashing purposes. The top of the curb shall be level and the slope of the roof shall be compensated for by the curb.

B. Curbs shall be a minimum of 18-gauge galvanize steel construction (or as deemed necessary by the curb manufacturer to support unit load) with fully mitered and welded corners and self-flashing without cant. The curb shall not sag more than 1" in 240" + or - when supporting the unit at the corners of curb only. The curb shall be internally reinforced with angle iron, factory insulated with 1½", 3 lb./ft^3 density fiberglass insulation, and shall be complete with factory installed pressure treated wood nailers. Coordinate sizes to match frames provided by others. When the project is located within 5 miles of a sea coast, curbs shall be of aluminum construction.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Installation shall be in strict accordance with the manufacturer's printed instructions and as detailed on the Drawings. Curb manufacturer shall coordinate with HVAC and General Contractor.

END OF SECTION

SECTION 23 05 48 - NOISE AND VIBRATION CONTROL, SEISMIC AND WIND RESTRAINT

PART 1 - GENERAL

1.01 DESCRIPTION

A. Furnish and install vibration control devices, materials, and related items. Perform all work as shown on the Drawings and as specified herein to provide complete vibration isolation systems in proper working order.

1.02 MATERIAL AND EQUIPMENT

A. Vibration isolation mounts shall be supplied by one of the following approved manufacturers:

1.	Amber/Booth Co. (Houston, TX)	A.B.
2.	Mason Industries, Inc. (Hauppauge, NY)	M.I.
3.	Kinetics Noise Control, Inc. (Dublin, OH)	K.N.C.
4.	Vibration Eliminator Co., Inc. (Copiague, NY)	V.E.
5.	Vibration Mountings & Controls, Inc. (Butler, NJ)	V.M.&C
6.	Vibro-Acoustics (Markham, ON, Canada)	V.A.

B. Unless otherwise specified, supply only new equipment, parts and materials.

C. Substitutions of equal equipment beyond the alternatives listed will be permitted only with the written permission of the Architect. Accompany each request for acceptance of substitute equipment with manufacturer's certified data proving the equivalence of the proposed substitute in quality and performance. The Architect shall be the final judge of the validity of the data submitted.

D. Unless otherwise approved by the Architect, field-installed vibration isolation equipment shall be furnished by a single manufacturer or his authorized representative, who shall also be responsible for all work specified in this section to be performed by the manufacturer.

1.03 REQUESTS FOR CHANGE

A. Any requests for changes to the specifications must be submitted in writing at least ten (10) days prior to bid closing. Approval will be given through a written addendum. Refer to Division 01 for additional requirements.

1.04 QUALITY ASSURANCE

A. Coordinate the size, location, and special requirements of vibration isolation equipment and systems with other trades. Coordinate plan dimensions with size of housekeeping pads.

B. Provide vibration isolators of the appropriate sizes, with the proper loading to meet the specified deflection requirements.

C. Supply and install any incidental materials such as mounting brackets, attachments and other accessories as may be needed to meet the requirements stated herein, even if not expressly specified or shown on the Drawings, without claim for additional payment.

D. Verify correctness of equipment model numbers and conformance of each component with manufacturer's specifications.

E. Should any rotating equipment cause excessive noise or vibration when properly installed on the specified isolators, the Contractor shall be responsible for rebalancing, realignment, or other remedial work required reducing noise and vibration levels. Excessive is defined as exceeding the manufacturer's specifications for the unit in question.

F. Upon completion of the work, the Architect or Architect's representative shall inspect the installation and shall inform the installing contractor of any further work that must be completed. Make all adjustments as directed by the Architect that result from the final inspection. This work shall be done before vibration isolation systems are accepted.

1.05 SUBMITTALS

A. Refer to related sections elsewhere for procedural instructions for submittals.

B. Before ordering any products, submit shop drawings of the items listed below. The shop drawings must be complete when submitted and must be presented in a clear, easily understood form. Incomplete or unclear presentation of shop drawings may be reason for rejection.

1. A complete description of products to be supplied, including product data, dimensions, specifications, and installation instructions.
2. Detailed selection data for each vibration isolator supporting equipment, including:
    a. The equipment identification mark;
    b. The isolator type;
    c. The actual load;
    d. The static deflection expected under the actual load;
    e. The specified minimum static deflection.
3. Steel rails, steel base frames, and concrete inertia bases showing all steel work, reinforcing, vibration isolator mounting attachment method, and location of equipment attachment bolts.
4. Special details necessary to convey complete understanding of the work to be performed.

C. Submission of samples may be requested for each type of vibration isolation device. After approval, samples will be returned for installation at the job if requested. All costs associated with submission of samples shall be borne by the Contractor.

1.06 DESIGN REQUIREMENTS

A. Design isolators for equipment installed outdoors to provide adequate restraint to withstand the force as required by code to any exposed surface of the isolated equipment. Isolators for outdoor equipment shall have bolt holes for attachment to equipment and to supports.

The vibration isolation Vendor shall submit verifying shear and over turning calculations, for their product and equipment installation arrangement, stamped by a licensed Professional Engineer. The design and supply of miscellaneous support steel above and below isolators will not be the responsibility of the vibration isolation manufacturer.

1.07 VIBRATION ISOLATION AND SEISMIC AND WIND RESTRAINT

A. Scope

1. Provide isolators, flexible connections, and equipment bases for all rotating, piston driven, or vibrating equipment.
2. Guarantee specified isolation system deflections.
3. Provide installation instructions, drawings, and field supervision to ensure proper installation and performance of all items specified in this section.
4. Design, furnish, and install attachment devices, anchor bolts, and seismic restraints that are required for seismic compliance for all equipment, apparatus piping, conduit and raceways, ductwork, and other components of the specified systems required by codes and standards. "Attachment Devices" are devices such as double-sided beam clamps, concrete inserts, and attachment plates that serve to secure the supported device into the structure.
5. Provide seismic and wind restraint types as described. If the item to be restrained is not listed, select appropriate restraint and submit for approval.
6. In addition, seismic bracing for Fire Protection systems shall conform to NFPA 13.

B. Definitions

1. "Attachment Devices" are devices such as double-sided beam clamps, concrete inserts, and attachment plates that serve to secure the supported device to the structure.
2. "Positive Attachment" is defined as a support location with a cast-in or wedge type expansion anchor, a double-sided beam clamp, or a welded or through bolted connection to the structure.
3. "Transverse Bracing" Restraint(s) applied to limit motion perpendicular or angular to the centerline of the pipe, duct, or conduit.
4. "Longitudinal Bracing" Restraint(s) applied to limit motion perpendicular or angular to the centerline of the pipe, duct, conduit, etc.
5. Life Safety Systems
    a. All systems involved with fire protection, including sprinkler piping, fire pumps, jockey pumps, fire pump control panels, service water supply piping, water tanks, and fire dampers.
    b. All systems involved with and/or connected to emergency power supply, including all generators, transfer switches, transformers and all circuits to fire equipment.
    c. All systems involved with and/or connected to emergency power supply, including all generators, transfer switches, transformers and all circuits to fire protection, smoke evacuation and/or emergency lighting systems.

C. Reference Codes and Standards

1. 2020 Florida Building Codes
2. "SMACNA Guidelines for Seismic Restraint of Mechanical Systems" – Second Edition (1998) with Addendum No. 1 (September 2000)
3. Structural references for the specific project listed
4. Seismic Design Category as per the structural plans
5. Wind forces for all rooftop equipment

D. Submittal Data Requirements

1. Submittals
   a. Catalog cuts or data sheets on specific products utilized, which detail compliance with the specification. Reference "TYPE" as per "PRODUCTS" section of this specification.
2. Shop Drawings
   a. Show base construction for equipment; include dimensions, weights, structural member sizes and support point locations.
   b. Indicate isolation devices selected with complete dimensional and deflection data before condition is accepted for installation.
   c. Calculate thrust for fan heads (axial and centrifugal fans) to determine whether thrust restraints are required.

E. Seismic and/or Wind Certification and Analysis

1. Seismic and/or wind restraint calculations shall be provided for all connections of equipment to the structure per the requirements of the structural plans and specifications. All performance of products (such as: strut, cable, anchors, clips, etc.) associated with restraints shall be supported with manufacturer's data sheets or certified calculations.
2. Seismic restraint calculations shall be based on the acceleration criteria required by local codes. Note: For roof-mounted equipment, both the seismic acceleration and wind loads shall be calculated; the highest load shall be utilized for the design of the restraints and isolators.
3. Calculations to support seismic or wind restraint design shall be stamped by a registered professional engineer with at least five years of seismic design experience.
4. Table elevations refer to the structural point of attachment of the equipment support system (i.e., use floor slab for floor supported equipment and the elevation of the slab above for suspended equipment).
5. Analysis shall indicate calculated dead loads, derived loads and materials utilized for connections to equipment and structure. Analysis shall detail anchoring methods, bolt diameter, embedment and/or weld length.
6. Certification and analysis report shall be submitted along with other HVAC submittals.

F. Manufacturer Inspection

1. Upon completion of installation of all vibration isolation and seismic restraint devices, a certification report prepared by the manufacturer shall be submitted in

writing to the Contractor indicating that all systems are installed properly and in compliance with the specifications. The report must identify those areas that require corrective measures or certify that none exist. Any field coordination type changes to the originally submitted seismic restraint designs must be clearly defined and detailed in this report.

PART 2 - PRODUCTS

2.01 VIBRATION ISOLATOR TYPES

A. General

1. All metal parts installed out-of-doors shall be corrosion resistant after fabrication. Galvanizing shall meet ASTM Salt Spray Test Standards and Federal Test Standard No. 14.
2. Isolators installed out-of-doors shall have base plates with bolt holes for fastening the isolators to the support members.
3. Isolator types are scheduled to establish minimum standards. At the Contractor's option, labor-saving accessories can be an integral part of isolators supplied to provide initial lift of equipment to operating height, hold piping at fixed elevations during installation and initial system filling operations, and similar installation advantages. Accessories and seismic restraint features must not degrade the isolation performance of the isolators.
4. Static deflection of isolators shall be as provided in the EXECUTION section and as shown on the Drawings. All static deflections stated are the minimum acceptable deflection for the mounts under actual load. Isolators selected solely on the basis of rated deflections are not acceptable and will be disapproved.

B. Type FSN (Floor Spring and Neoprene)

1. FSN isolators shall be freestanding and laterally stable without any housing. Spring diameter shall be not less than 0.8 of the compressed height of the spring at the rated load. Springs shall have a minimum additional travel-to-solid equal to 50% of the rated deflection. Springs shall be so designed that the ratio of horizontal stiffness to vertical stiffness is approximately 1. Mounts shall have leveling bolts.
2. The spring element in the isolator shall be set in a neoprene cup and have a steel washer or a flat surface in contact with the neoprene to distribute the load evenly over the bearing surface of the neoprene. Alternatively, each isolator shall be mounted on a Type NP isolator. If the NP isolator is used, a rectangular bearing plate of appropriate size shall be provided to load the pad uniformly within the manufacturer's recommended range. If the isolator is to be fastened to the building and the NP isolator is used, the holes in the isolator base plate shall be oversized and GROMMETS shall be provided for each base plate bolt hole.
3. If the basic spring isolator has a neoprene friction pad on its base and an NP isolator is to be added to the base, a galvanized steel, stainless steel or aluminum bearing plate shall be used between the friction pad and the NP isolator. If the isolator is outdoors, bearing plates shall not be made of galvanized steel. The NP isolator, bearing plate and friction pad shall be permanently adhered to one another and to the bottom of the isolator base plate.

4. Type FSN isolators shall be one of the following products with the appropriate neoprene pad (if used) selected from Type NP or approved equal:
   a. Type SW A.B.
   b. Type SLF M.I.
   c. Type FDS K.N.C.
   d. Type OST V.E.
   e. Series AC V.M.&C.
   f. Type CM V.A.

C. Type FSNTL (Floor Spring and Neoprene Travel Limited)

1. FSNTL isolators shall be freestanding and laterally stable without any housing. Spring diameter shall be not less than 0.8 of the compressed height of the spring at the rated load. Spring shall have a minimum additional travel-to-solid equal to 50% of the rated deflection. Springs shall be so designed that the ratio of horizontal stiffness to vertical stiffness is approximately 1. Mounts shall have leveling bolts. Mounts shall have vertical travel limit stops to control extension when weight is removed. The travel limit stops shall be capable of serving as blocking during erection of the equipment. A minimum clearance of 1/4" shall be maintained around restraining bolts and between the limit stops and the spring to avoid interference with the spring action.
2. The spring element in the isolator shall be set in a neoprene cup and have a steel washer or a flat surface in contact with the neoprene to distribute the load evenly over the bearing surface of the neoprene. Alternatively, each isolator shall be mounted on a Type NP isolator. If the NP isolator is used, a rectangular bearing plate of appropriate size shall be provided to load the pad uniformly within the manufacturer's recommended range. If the isolator is to be fastened to the building and the NP isolator is used, the holes in the isolator base plate shall be oversized and GROMMETS shall be provided for each base plate bolt hole.
3. If the basic spring isolator has a neoprene friction pad on its base and an NP isolator is to be added to the base, a galvanized steel, stainless steel or aluminum bearing plate shall be used between the friction pad and the NP isolator. If the isolator is outdoors, bearing plates shall not be made of galvanized steel. The NP isolator, bearing plate and friction pad shall be permanently adhered to one another and to the bottom of the isolator base plate.
4. Type FSNTL isolators shall be one of the following products, with the appropriate neoprene pad (if used) selected from Type NP or approved equal:
   a. Type CT A.B.
   b. Type SLR M.I.
   c. Type FLS K.N.C.
   d. Type KW V.E.
   e. Series AWR V.M.&C.
   f. Type CSR V.A.

   For regions where G force values exceed 0.5G (wind or seismic) a stronger (more rigid housing) isolator is required.
   g. Type SCSR V.A.

D. Type FN (Floor Neoprene)

1. NP isolators shall be neoprene-in-shear type with steel reinforced top and base. All metal surfaces shall be covered with neoprene. The top and bottom surfaces shall be ribbed. Bolt holes shall be provided in the base and the top shall have a threaded fastener. The mounts shall include leveling bolts that may be rigidly connected to the equipment.
2. Type FN isolators shall be one of the following products or approved equal:
   a. Type RVD A.B.
   b. Type ND M.I.
   c. Type RD K.N.C.
   d. Type D44 V.E.
   e. Series RD V.M.&C.
   f. Type RD V.A.

E. Type FNC (Floor Neoprene Constrained)

1. FNC isolators shall incorporate bridge-bearing neoprene elements with all-directional restraint. The mount shall consist of a ductile iron casting containing two (2) separated and opposing molded neoprene elements. The elements shall prevent the central threaded sleeve and attachment bolt from contacting the casting during normal operation. Bolt holes shall be provided in the base and the top shall have a threaded fastener.
2. Type FNC isolators shall be one of the following products or approved equal:
   a. Type BR M.I.
   b. Series RSM V.M.&C.
   c. Type SRD V.A.

F. Type PCF (Pre-compressed Fiberglass)

1. PCF isolator blocks shall be made of molded inorganic glass fiber that is individually coated and sealed with an impervious elastomeric membrane. Fiberglass shall be severely overloaded during the manufacturing process to stabilize the material into a product that is permanent and has consistent, predictable dynamic properties.
2. Type PCF isolators shall be one of the following products or approved equal:
   a. Type KIP K.N.C.

G. Type NP (Neoprene Pad)

1. NP isolators shall be one layer of 5/16" to 3/8" thick ribbed or waffled neoprene. The pads shall be sized so that they will be loaded within the manufacturer’s recommended range.
2. Type NP isolators shall be one of the following products or approved equal:
   a. Type NR A.B.
   b. Type W M.I.
   c. Type NPS K.N.C.
   d. Type 200N V.E.
   e. Series Maxi-Flex V.M.&C.
   f. Type N V.A.

H. Type DNP (Double Neoprene Pad)

1. DNP isolators shall be formed by two layers of 1/4" to 3/8" thick ribbed or waffled neoprene, separated by a galvanized steel, stainless steel, or aluminum plate. If the isolator is outdoors, the plate shall not be made of galvanized steel. These layers shall be permanently adhered together. The pads shall be sized so that they will be loaded within the manufacturer's recommended range.
2. Type DNP isolators shall be formed from one of the following products or approved equal:

a.	Type NR	A.B.
b.	Type WSW	M.I.
c.	Type NPS	K.N.C.
d.	Type 200N (Multilayers)	V.E.
e.	Series Maxi-Flex	V.M.&C.
f.	Type NP	V.A.

I. Type HSN (Hanger Spring and Neoprene)

1. HSN isolators shall consist of a freestanding and laterally stable steel spring and a neoprene element in series, contained within a steel housing. Spring diameters and hanger housing lower hole sizes shall be large enough to permit the hanger rod to swing through a 30 degrees arc before contacting the housing. Alternatively, other provisions shall be made to allow for a 30 degrees arc of movement of the bottom hanger rod without contacting the isolator housing. Spring diameter shall be not less than 0.8 of the compressed height of the spring at the rated load. Spring elements shall have a minimum additional travel-to-solid equal to 50% of the rated deflection. The neoprene element shall be designed to have a 0.3" minimum static deflection. The deflection of both the spring element and the neoprene element shall be included in determining the overall deflection of Type HSN isolators.
2. A pre-compressed glass fiber element may be substituted for the neoprene element.
3. Type HSN isolators shall be one of the following products or approved equal:

a.	Type BSR-A	A.B.
b.	Type 30N	M.I.
c.	Type SRH or SFH	K.N.C.
d.	Type SNRC	V.E.
e.	Type RSH 30A or RSHSC	V.M.&C.
f.	Type SHR	V.A.

J. Type HN (Hanger Neoprene)

1. HN isolators shall consist of a neoprene-in-shear element contained within a steel housing. A neoprene neck bushing shall be provided where the hanger rod passes through the hanger housing to prevent the rod from contacting the hanger housing.
2. A pre-compressed glass fiber element may be substituted for the neoprene element.
3. Type HN isolators shall be one of the following products or approved equal:

a.	Type BRD-A	A.B.
b.	Type HD	M.I.

c.	Type RH or FH	K.N.C.
d.	Type 3C	V.E.
e.	Type RHD	V.M.&C.
f.	Type NH	V.A.

2.02 EQUIPMENT BASES

A. Type BSR (Base - Steel Rail)

1. Steel rail bases shall consist of structural steel sections sized to provide a rigid beam that will not twist, deform, or deflect in any manner that will negatively affect the supported equipment or the vibration isolation mounts. Rail bases shall include mounting brackets for attachment of vibration isolators.
2. Type BSR bases shall be one of the following products or approved equal:

a.	Type C or CIS	A.B.
b.	Type R or ICS	M.I.
c.	Type KRB or KFB	K.N.C.
d.	Type CS	V.E.
e.	Type WFR	V.M.&C.
f.	Type CS	V.A.

B. Type BSF (Base - Steel Frame)

1. Steel frame bases shall consist of structural steel sections sized, spaced, and connected to form a rigid base which will not twist, rack, deform, or deflect in any manner which will negatively affect the supported equipment, or the vibration isolation mounts. Frames shall be adequately sized to support basic equipment units and motors plus any associated pipe elbow supports, duct elbow supports, electrical control elements, or other components closely related and requiring resilient support in order to prevent vibration transfer to the building structure. The depth of steel frame bases shall be at least 1/10 the longest dimension of the base supported between isolators and not less than 6". The base footprint shall be large enough to provide stability for supported equipment.
2. Frame bases shall include side mounting brackets for attachment to vibration isolators. Mounting brackets shall be located on the sides of the base that are parallel to the axis of rotation of the supported equipment.
3. Type BSF bases shall be one of the following products or approved equal:

a.	Type WX	A.B.
b.	Type WFSL	M.I.
c.	Type SFB	K.N.C.
d.	Type HB	V.E.
e.	Series WFB	V.M.&C.
f.	Type CIS	V.A.

C. Type BIB (Base - Inertia Base)

1. Inertia bases shall be formed of stone-aggregate concrete (150 lb/cu. ft.) and appropriate steel reinforcing cast between welded or bolted perimeter structural

steel channels. Inertia bases shall be built to form a rigid base that will not twist, rack, deform, deflect, or crack in any manner that would negatively affect the supported equipment or the vibration isolation mounts. Inertia bases shall be adequately sized to support basic equipment units and motors plus any associated pipe elbow supports, duct elbow supports, electrical control elements, or other components closely related and requiring resilient support in order to prevent vibration transfer to the building structure. Inertia base depth shall be at least 1/12 the longest dimension of the base supported between isolators and not less than 6". The base footprint shall be large enough to provide stability for supported equipment. Inertia bases shall include side mounting brackets for attachment to vibration isolators. Mounting brackets shall be located on the sides of the base that are parallel to the axis of rotation of the supported equipment. Concrete may be provided by the General Contractor.

2. Frame and reinforcement for Type BIB bases shall be one of the following products or approved equal:

a.	Type CPF	A.B.
b.	Type KSL or BMK	M.I.
c.	Type CIB-L or CIB-H	K.N.C.
d.	Type SN	V.E.
e.	Series MPF or WPF	V.M.&C.
f.	Type CIB	V.A.

D. Type RC-1 (Roof Curb, Type 1)

1. Type RC-1 isolation bases shall be a prefabricated assembly consisting of an extruded aluminum frame and steel spring isolation system that fits over the roof curb and under the isolated equipment. The aluminum frame shall be sufficiently rigid to support the equipment load without detrimental twist or deflection. Spring isolators shall be selected and positioned along the curb to achieve the minimum static deflection called for in the schedule. The static deflection shall be constant around the entire periphery of the base. Springs shall be free standing, laterally stable with a diameter of not less than 0.8 times the compressed height, and have additional travel-to-solid that is at least 50% of the rated deflection. Resilient neoprene snubbers shall be provided at the corners of the base to limit equipment movement to 1/4" under wind load.
2. The isolation curb base shall be made weather tight by sealing all around the periphery with closed cell neoprene or flexible membrane that shall in no way inhibit the vibration isolation of the spring elements. Closed cell sponge gasketing or field caulking shall be used between the equipment unit and the isolation curb base and between the isolation curb and roof curb to form a weather-tight seal. Each spring isolator used in the curbs shall be weather-protected as described in the PRODUCTS section under General.
3. Type RC-1 vibration isolation curb bases shall be supplied by the isolator manufacturer and shall be one of the following products or approved equal:

a.	Type RTIR	A.B.
b.	Type CMAB	M.I.
c.	Type ASR	K.N.C.
d.	Type AR	V.E.
e.	Series AXR	V.M.&C.

f. Type VCR V.A.

E. Type RC-2 (Roof Curb, Type 2)

1. Type RC-2 isolation bases shall be a prefabricated assembly consisting of a structural steel frame and steel spring isolation system that also forms the roof curb under the isolated equipment. The steel frame shall be sufficiently rigid to support the equipment load without detrimental twist or deflection. Spring isolators shall be selected and positioned along the curb to achieve the minimum static deflection called for in the schedule. The static deflection shall be constant around the entire periphery of the base. Springs shall be free standing, laterally stable with a diameter of not less than 0.8 times the compressed height, and have additional travel-to-solid that is at least 50% of the rated deflection. Spring isolators shall include travel limit stops that are capable of serving as blocking during erection of the equipment. A minimum clearance of 1/4" shall be maintained around restraining bolts as they pass through the limit stop brackets. Springs and limits stops shall be provided at the corners of the base to limit equipment movement to 1/4" under wind load.
2. The isolation curb base shall be made weather tight by sealing all around the periphery with closed cell neoprene, flexible membrane or light gauge spring metal loop, which shall in no way inhibit the vibration isolation of the spring elements. A closed cell sponge gasket or field caulking shall be used between the equipment unit and the isolation curb base and between the isolation curb and roof curb to form a weather-tight seal. Each spring isolator used in the curbs shall be weather-protected as described in the PRODUCTS section under General.
3. Type RC-2 vibration isolation curb bases shall be supplied by the isolator manufacturer and shall be one of the following products or approved equal:
   a. Type RSC M.I.
   b. Type SSR K.N.C.
   c. Vibrocurb ThyCurb
   d. ARTR/VCR V.A.

F. Type RP-1 (Low Profile Structural Roof Platform for Air Cooled Chillers and Cooling Towers)

1. Type RP-1 isolation platform bases shall be a prefabricated assembly consisting of a structural steel frame and steel spring isolation system that also forms the roof platform under the isolated equipment. The steel frame shall be sufficiently rigid to support the equipment load without detrimental twist or deflection. Spring isolators shall be selected and positioned along the curb to achieve the minimum static deflection called for in the schedule. Springs shall have appropriate wind and seismic restraint. The static deflection shall be constant around the entire periphery of the base. Springs shall be free standing, laterally stable with a diameter of not less than 0.8 times the compressed height and have additional travel-to-solid that is at least 50% of the rated deflection. Spring isolators shall include travel limit stops that are capable of serving as blocking during erection of the equipment.
2. A minimum clearance of 1/4" shall be maintained around restraining bolts as they pass through the limit stop brackets. Springs and limits stops shall be provided at the corners of the base to limit equipment movement to 1/4" under wind load.

3. A galvanized insulated and cross broken sloped solid top shall be provided to shed water. If project location is within 50 miles of a seacoast area, the top section shall be fabricated from Type 304 stainless steel.
4. Platform access doors or sections shall be installed as required for servicing curb components or accessories.
5. The platform shall be constructed to an appropriate height so as to match the pitch of the roof insulation with adequate height to meet code minimum of 10" above final roof membrane.
6. The isolation shall allow (¼") movement before resisting wind loads in any lateral direction.
7. The isolation platform shall be designed to meet all seismic loads and wind loading as defined by the building code having jurisdiction. Calculations shall be provided and stamped by a Professional Engineer.
8. Type RP-1vibration isolation Platform shall be supplied by the isolator manufacturer and shall be one of the following products or approved equal:
   a. VSPS V.A.

2.03 VIBRATION ISOLATOR SCHEDULE

Equipment Type	Base Type	Isolator Type	Minimum Deflection
Air Handling Units – Floor Mounted < 1 HP	-	DNPx2	1/10"
Air Handling Units – Floor Mounted > 1 HP	-	FNC	3/8"
Air Handling Units – Internally Isolated	-	DNPx2	1/10"
Air Handling Units (Including PIUs) – Suspended < 1 HP	-	HN	3/8"
Air Handling Units – Suspended > 1 HP	-	HSN	1"
Boilers	-	FSN	1"
Cooling Towers	-	FSNTL	4"
Cooling Towers (Low Profile Platform)	-	FSNTL	3"
Dedicated Outdoor Air Rooftop Units <25 Tons	-	RC-2	1"
Dedicated Outdoor Air Rooftop Units >25 Tons	-	RC-2	2"
Fan Coil Units – Floor Mounted	-	DNP	1/10"
Fan Coil Units – Suspended	-	HN	3/8"
Fans – Floor Mounted < 1 HP	BSF	DNPx2	1/10"
Fans – Floor Mounted > 1 HP	BSF	FNC	3/8"
Fans – Suspended < 1 HP	-	HN	3/8"
Fans – Suspended > 1 HP	-	HSN	1"
Generator	-	FSNTL	2.5"
Generator Exhaust Pipe	-	HSN	2"
Heat Exchangers	-	FSNTL	1"
Packaged Roof Top Units <25 Tons	-	RC-2	1"
Packaged Roof Top Units >25 Tons	-	RC-2	2"
Pumps - Floor Mounted < 1 HP	-	DNP	1/10"
Pumps - Floor Mounted < 5 HP	BIB	FN	3/8"
Pumps - Floor Mounted > 5 HP	BIB	FSN	2"
Pumps - Suspended Inline	-	HSN	2"
Pumps – Floor Mounted Inline	SIPS	FSNTL	2"
Split System Condensing Units < 5 Tons	-	NP	1/10"

Split System Condensing Units > 5 Tons	BSR	FSN	1"
Split System Heat Pump Units < 5 Tons	-	NP	1/10"
Split System Heat Pump Units > 5 Tons	BSR	FSN	1"
VRF/VRV		DNP	1/10"
Water-Cooled Self-Contained Units (Internally Isolated)	-	DNPx2	1/10"
Water Cooled Self Contained Units	-	FSN	2"
Water Source Heat Pumps – Floor Mounted < 5 Tons	-	NP	1/10"
Water Source Heat Pumps – Floor Mounted > 5 Tons	-	FSN	1"
Water Source Heat Pumps – Suspended < 5 Tons	-	HN	3/8"
Water Source Heat Pumps – Suspended > 5 Tons	-	HSN	1"

2.04 RESILIENT PENETRATION SLEEVE/SEAL

A. Resilient penetration sleeve/seals shall be field-fabricated from a pipe or sheet metal section that is l/2" to 3/4" larger than the penetrating element in all directions around the element, and shall be used to provide a sleeve through the construction penetrated. The sleeve shall extend 1" beyond the penetrated construction on each side. The space between the sleeve and the penetrating element shall be packed with glass fiber or mineral wool to within 1/4" of the ends of the sleeve. The remaining 1/4" space on each end shall be filled with acoustical sealant to form an airtight seal. The penetrating element shall be able to pass through the sleeve without contacting the sleeve. Alternatively, prefabricated sleeves accomplishing the same result are acceptable.

2.05 RESILIENT LATERAL SUPPORTS

A. These units shall either be a standard product of the vibration isolator manufacturer, or be custom fabricated from standard components. These units shall incorporate neoprene isolation elements similar to Type FN that are specifically designed to provide resilient lateral bracing of ducts or pipes.

B. Resilient lateral supports shall be one of the following products or approved equal:

1. Type Custom A.B.
2. Type ADA M.I.
3. Type RGN K.N.C.
4. Type VERG or VPL V.E.
5. Type MDPA V.M.&C.
6. Type RD V.A.

2.06 FLEXIBLE DUCT CONNECTIONS

A. Flexible duct connections shall be made from coated fabric. The clear space between connected parts shall be a minimum of 3", and the connection shall have a minimum of 1.5" of slack material.

2.07 FLEXIBLE PIPE CONNECTIONS

A. Flexible pipe connections shall be fabricated of multiple plies of nylon cord, fabric, and neoprene, and shall be vulcanized so as to become inseparable and homogeneous. Flexible connections shall be formed in a double sphere shape, and shall be able to accept compressive, elongating, transverse, and angular movements.

B. The flexible connections shall be selected and specially fitted, if necessary, to suit the system temperature, pressure, and fluid type. In addition, suitable flexible connections should be selected, if possible, which do not require rods or cables to control extension of the connector.

C. Connectors for pipe sizes 2" or smaller shall have threaded female union couplings on each end. Larger sizes shall be fitted with metallic flange couplings.

D. Flexible pipe connections shall be one of the following or an approved equal:

1.	Type 2600 or 2655	A.B.
2.	Type Twin Sphere	Metraflex
3.	Type MFTNC or MFTFU	M.I.
4.	Double Sphere Flexible Connectors	V.E.
5.	Series VMT or VMU	V.M.&C.
6.	Type Twin Sphere	Twin City Hose

2.08 THRUST RESTRAINTS

A. Thrust restraints shall consist of a spring element in series with a neoprene pad. The unit shall be designed to have the same deflection due to thrust-generated loads as specified for the isolators supporting the equipment. The spring element shall be contained within a steel frame and be designed so it can be pre-compressed at the factory to allow for a maximum of 1/4" movement during starting or stopping of the equipment. Allowable movement shall be field-adjustable. The assembly shall be furnished complete with rods and angle brackets for attachment to both the equipment and the adjacent fixed structural anchor. The thrust restraints shall be installed on the discharge of the fan so that the restraint rods are in tension. Assemblies that place the rods in compression are not acceptable. The holes in the spring restraint brackets through which the restraint rods pass must be oversized to prevent contact between the brackets and rods.

B. Thrust restraints shall be one of the following products or an approved equal:

1.	Type TRK	A.B.
2.	Type HSR	K.N.C.
3.	Type WB	M.I.
4.	Thrust Restraint	V.E.
5.	Type SHR	V.A.

2.09 GROMMETS

A. Grommets shall be made of neoprene or neoprene impregnated duct that is specially formed to prevent bolts from directly contacting the isolator base plate, and shall be sized so that they will be loaded within the manufacturer’s recommended load range.

B. Grommets shall either be custom made by combining a neoprene washer and sleeve, or be one of the following products or an approved equal:

1.	Type Isogrommets	MBIS, Inc. (Bedford Heights, OH)
2.	Type WB	Barry Controls (Brighton, MA)
3.	Type HG	Mason Industries Inc. (Hauppauge, NY)
4.	Type GW	V.A.

2.10 ACOUSTICAL SEALANT

A. Sealants for acoustical purposes as described in this specification shall be silicone or one of the resilient, non-hardening sealants indicated below:

1.	Acoustical sealant	D.A.P.
2.	BR-96 or AC-20 (AC-20 FTR - Fire Rated)	Pecora
3.	Sonoloc	Sanborn
4.	Acoustical Sealant #834 (Acrylic Latex)	Tremco
5.	Acoustical sealant	U.S.G.

PART 3 - EXECUTION

3.01 APPLICATION

A. General

1. Refer to the PRODUCTS section of this specification for vibration isolation devices identified on the Drawings or specified herein.
2. The static deflection of all isolators specified herein is the minimum acceptable deflections for the mounts under actual load. Isolators selected solely on the basis of rated deflection are not acceptable and will be disapproved.

B. Major Equipment Isolation

1. Unless otherwise shown or specified, all floor-mounted major equipment shall be set on housekeeping pads. See architectural or structural drawings for details.
2. Types and minimum static deflections of vibration isolation devices for major equipment items shall be as scheduled on the Drawings or specified hereunder.
3. Flexible duct connections shall be installed at all fan unit intakes, fan unit discharges, and wherever else shown on the Drawings.
4. Flexible pipe connections shall be installed at all pipe connections to vibration-isolated equipment in the positions shown on the Drawings.
5. Electrical connections to vibration-isolated equipment shall be flexible, as called for in the electrical portion of the specification.
6. Thrust restraints shall be installed on all suspended fans and on all floor-mounted fans developing 4" or more of static pressure, unless the horizontal component of the thrust force can be demonstrated to be less than 10% of the equipment weight.

C. Miscellaneous HVAC Equipment Isolation

1. Miscellaneous pieces of HVAC equipment, such as converters, pressure reducing stations, dryers, strainers, storage tanks, condensate receiver tanks, and expansion tanks, which are connected to isolated piping systems, shall be vibration-isolated from the building structure by Type NP or Type HN isolators (selected for 0.1" static deflection), unless their position in the piping system requires a higher degree of isolation as called for under Pipe Isolation.

D. Pipe Isolation

1. All chilled water, condenser water, hot water, steam, refrigerant, drain and engine exhaust piping that is connected to vibration-isolated equipment shall be isolated from the building structure within the following limits:
   a. Within mechanical rooms;
   b. Within 50' total pipe length of connected vibration-isolated equipment (chillers, pumps, air handling units, pressure reducing stations, etc.);
   c. At every support point for piping that is greater than 4" in diameter.
2. Piping shall be isolated from the building structure by means of vibration isolators, resilient lateral supports, and resilient penetration sleeve/seals.
3. Isolators for the first three support points adjacent to connected equipment shall achieve one half the specified static deflection of the isolators supporting the connected equipment. When the required static deflection of these isolators is greater than 1/2", Type FSN or HSN isolators shall be used. When the required static deflection is less than or equal to 1/2", Type FN or HN isolators shall be used. All other pipe support isolators within the specified limits shall be either Type FN or HN achieving at least 1/4" static deflection.
4. Where lateral support of pipes is required within the specified limits, this shall be accomplished by use of resilient lateral supports.
5. Pipes within the specified limits that penetrate the building construction shall be isolated from the building structure by use of resilient penetration sleeve/seals.
6. Provide flexible pipe connections as called for under Major Equipment above and wherever shown on the Drawings.

E. Duct Isolation

1. All sheet metal ducts and air plenums that are within mechanical rooms or within a distance of 50' total duct length of connected vibration-isolated equipment (whichever is longer) shall be isolated from the building structure by Type FN, PCF or HN isolators. All isolators shall achieve 0.1" minimum static deflection.
2. Ducts within the specified limits that penetrate the building construction shall be isolated from the building structure by use of resilient penetration sleeve/seals.
3. Flexible duct connections shall be provided as called for above under Major Equipment and wherever shown on the Drawings.

3.02 INSTALLATION OF VIBRATION ISOLATION EQUIPMENT

A. General

1. Locations of all vibration isolation devices shall be selected for ease of inspection and adjustment as well as for proper operation.
2. Installation of vibration isolation equipment shall be in accordance with the manufacturer's instructions.

B. Isolators

1. All vibration isolators shall be aligned squarely above or below mounting points of the supported equipment.
2. Isolators for equipment with bases shall be located on the sides of the bases which are parallel to the equipment shaft unless this is not possible because of physical constraints.
3. Locate isolators to provide stable support for equipment, without excess rocking. Consideration shall be given to the location of the center of gravity of the system and the location and spacing of the isolators. If necessary, a base with suitable footprint shall be provided to maintain stability of supported equipment, whether or not such a base is specifically called for herein.
4. If a housekeeping pad is provided, the isolators shall bear on the housekeeping pad and the isolator base plates shall rest entirely on the pad.
5. Hanger rods for vibration-isolated support shall be connected to major structural members, not the floor slab between major structural members. Provide suitable intermediate support members as necessary.
6. Vibration isolation hanger elements shall be positioned as high as possible in the hanger rod assembly, but not in contact with the building structure, and so that the hanger housing may rotate a full 360 degrees about the rod axis without contacting any object.
7. Parallel running pipes may be hung together on a trapeze that is isolated from the building. Isolator deflections must be the greatest required by the provisions for pipe isolation for any single pipe on the trapeze. Do not mix isolated and un-isolated pipes on the same trapeze.
8. Pipes, ducts and equipment shall not be supported from other pipes, ducts and equipment.
9. Resiliently isolated pipes, ducts and equipment shall not come in rigid contact with the building construction or rigidly supported equipment.
10. The installed and operating heights of equipment supported by Type FSNTL isolators or with Type RC-2 isolation bases shall be identical. Limit stops shall be out of contact during normal operation. Adjust isolators to provide 1/4" clearance between the limit stop brackets and the isolator top plate, and between the travel limit nuts and travel limit brackets.
11. Adjust all leveling bolts and hanger rod bolts so that the isolated equipment is level and in proper alignment with connecting ducts or pipes.

C. Bases

1. No equipment unit shall bear directly on vibration isolators unless its own frame is suitably rigid to span between isolators and such direct support is approved by the equipment manufacturer. This provision shall apply whether or not a base frame is called for on the schedule. In the case that a base frame is required for the unit because of the equipment manufacturer's requirements and is not specifically

called for on the equipment schedule, a base frame recommended by the equipment manufacturer shall be provided at no additional expense.

2. Unless otherwise indicated, there is to be a minimum operating clearance of 1" between steel rails, steel frame bases or inertia bases and the floor beneath the equipment. The isolator mounting brackets shall be positioned and the isolators adjusted so that the required clearance is maintained. The clearance space shall be checked by the Contractor to ensure that no construction debris has been left to short circuit or restrict the proper operation of the vibration isolation system.
3. Isolation bases shall be installed in strict accordance with the manufacturer's instructions.

D. Flexible Duct Connections

1. Prior to installation of the flexible connection, sheet metal ducts and plenum openings shall be squarely aligned with the fan discharge, fan intake, or adjacent duct section and the gap between connected parts shall be uniform. Flexible duct connections shall not be installed until this provision is met. There shall be no metal-to-metal contact between connected sections, and the fabric shall not be stretched taut.

E. Flexible Pipe Connections

1. Install flexible pipe connections in strict accordance with the manufacturer's instructions.

F. Thrust Restraints

1. Thrust restraints shall be attached on each side of the fan parallel to the thrust force. This may require custom brackets or standoffs. The body of the thrust restraint shall not come in contact with the connected elements. Thrust restraints shall be adjusted to constrain equipment movement to the specified limit.

G. Grommets

1. Where grommets are required at hold down bolts of isolators, bolt holes shall be properly sized to allow for grommets. The hold down bolt assembly shall include washers to distribute load evenly over the grommets. Bolts and washers shall be galvanized.

H. Resilient Penetration Sleeve/Seals

1. Maintain an airtight seal around the penetrating element and prevent rigid contact between the penetrating element and the building structure. Fit the sleeve tightly to the building construction and seal airtight on both sides of the construction penetrated with acoustical sealant.

END OF SECTION

SECTION 23 05 93 - TESTING, ADJUSTING AND BALANCING (TAB)

PART 1 - GENERAL

1.01 DESCRIPTION

A. Refer to specification section 23 00 00 - HVAC General, all of which applies to work described in this section as if written in full herein.

B. The work described by this section of the specifications consists of furnishing all materials, instruments, labor, and appurtenances to test, adjust and balance all of the HVAC systems furnished and installed under Division 23 of the specifications.

C. The TAB agency shall be a subcontractor of the General Contractor and shall not report to or be paid by the HVAC Contractor. The HVAC subcontractor shall be responsible to cooperate with and provide for the balancing subcontractor any and all materials, services, labor, etc. to facilitate completion of the balancing work.

1.02 QUALITY ASSURANCE

A. The TAB agency and its specialists shall be certified members of Associated Air Balance Council (AABC) or certified by the National Environmental Balance Bureau (NEBB) to perform TAB service for HVAC. The certification shall be maintained for the entire duration of duties specified herein. The TAB agency shall have been in business for at least the past five years and must be free of disciplinary action by either the AABC or the NEBB during that time.

B. All TAB technicians performing actual TAB work shall be experienced and must have done satisfactory work on a minimum of 3 projects comparable in size and complexity of this project and must be certified so by the TAB agency in writing.

C. The basic instrumentation shall be calibrated to accuracy requirements by its manufacturer, AABC or NEBB Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems. Submit calibration history of the instruments to be used for test and balance purpose during the preliminary and final submittal phase.

D. One or more of the applicable AABC, NEBB or SMACNA publications, supplemented by the ASHRAE Handbooks and requirements stated herein shall be the basis for planning, procedures, tolerances and reports. Final report shall cite the exact names of publications used as a basis or reference for the TAB work or reports.

1.03 DEFINITIONS

A. Retain definition(s) remaining after this Section has been edited.

B. AABC: Associated Air Balance Council.

C. NEBB: National Environmental Balancing Bureau.

D. TAB: Testing, adjusting, and balancing.

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

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

PART 2 - PRODUCTS

2.01 MATERIALS

A. Provide plastic plugs to seal holes drilled in ductwork for test purposes.

B. Provide for repair of insulation removed or damaged for TAB work to match installation.

PART 3 - EXECUTION

3.01 TAB PROCEDURES

A. TAB shall be performed in accordance with the requirements of the Standard under which the TAB agency is certified, either AABC or NEBB.

B. During TAB all related system components shall be in full operation including the Automatic Temperature Controls system. Fan and pump rotation, motor loads and equipment vibration shall be checked and corrected as necessary before proceeding with TAB. Set controls and/or block off parts of distribution systems to simulate design operation of variable volume air or water systems for test and balance work.

C. Adjustment of the temperature controls shall be coordinated by the TAB work specialist in conjunction with the Building Automation System/Automatic Temperature Control Company's Engineer. Both shall cooperate to simulate a complete cycle for every system in every mode of operation (automatic, economizer, fire emergency, etc.).

D. Coordinate TAB procedures with any phased construction completion requirements for the project. Provide TAB reports for each phase of the project prior to partial final inspections of each phase of the project.

E. Test and balance required in dwelling units must be completed and the TAB report submitted prior to occupancy. Coordinate with the general contractor, owner's representative, and mechanical subcontractor to schedule TAB well in advance of occupancy.

F. Record dates and time of day of all tests, and ambient conditions (dry bulb and wet bulb).

3.02 AIR SYSTEMS TAB

A. Systems shall be tested, adjusted and balanced so that air quantities and temperatures at outlets are as shown on the Contract Drawings and so that the distribution from supply outlets is uniform over the face of each outlet.

B. Direct reading velocity meters may be used for comparative adjustment of individual outlets, but air quantities in ducts having velocities of 1,000 feet per minute or greater shall

be measured by means of pitot tubes and inclined gauge manometers. Instrument test opening enclosures shall be provided as required at the direction of the TAB agency.

C. Adjustments shall be made in such a manner that splitter and volume adjusters close to air outlets will have the least pressure drop consistent with volume requirements. Primary balancing shall be obtained by adjustment of the dampers at branch duct take-offs. Adjustable fan drives shall be used for making final adjustments of total air quantities. Additional dampers or other air volume adjusters required to accomplish the balancing and adjusting shall be furnished and installed as part of the HVAC work.

D. Artificially load air filters by partial blanking to produce air pressure drop of at least 90 percent of the design final pressure drop.

E. Check and readjust factory set minimum and maximum air terminal unit flow rates if necessary. Balance air distribution on full cooling maximum. Reset room thermostats and check operation from maximum to minimum cooling, to the heating mode, and back to cooling. Record and report the heating coil leaving air temperature when in the maximum heating mode.

F. Adjust fan speeds to provide design air flow. Adjust V-belt drives, including fixed pitch pulley requirements.

G. After completion of the testing, adjusting and balancing of the air systems, provide electronic files (e.g. PDFs, etc.) of the complete test report showing the minimum following information which shall be submitted to the Engineer for review:

1. Systems inspection narrative on equipment and installation for conformance with design
2. Duct Air Leakage Test Report
3. Systems Readiness Report
4. TAB report covering flow balance and adjustments, performance tests, required information:
    a. Location of each air outlet or inlet. This shall be presented in the form of a reduced size floor plan showing outlet number keyed to the outlet number in the report.
    b. Dimensions or size of each outlet or inlet
    c. Type and manufacturer of diffusers, grilles, registers. Indicate duty as supply, return, exhaust, etc.
    d. CFM of air as indicated on the Drawings for each outlet or inlet with corresponding velocity
    e. Velocity of air as measured and corresponding cfm at which system has been balanced and adjusted, for each outlet or inlet
    f. Velocity of air measured and corresponding cfm, after each complete system has been balanced and adjusted, for each main branch or zone duct at the supply fan, the return fan and the exhaust fan, as the case may be
    g. After each complete system has been balanced and adjusted, the total cfm at fan discharge, the total return air to the apparatus, the total outside air to the apparatus, the total outside air to the apparatus, static pressure at fan

outlet, total static pressure for apparatus, fan speed, motor amperage for each phase and voltage

5. Narrative of uncorrected installation deficiencies noted during TAB and applicable explanatory comments on test results that differ from design requirements.

H. The above testing, adjusting, and balancing shall be performed for the first season of the year, cooling season or heating season, which occurs at the completion of the building. Additional balancing and adjusting which may be required for the season of the year next following shall be performed as part of the work under this specification.

I. For air conditioning systems with adaptive dehumidification cycle, test equipment in the conventional cooling mode, the dehumidification (hot gas) mode and the cooling with enhanced dehumidification (warm liquid) mode and record leaving air temperatures (db/wb) for each mode.

J. Ventilation air distribution systems (outdoor air and exhaust air) shall be balanced to achieve the airflow rates indicated on the drawings. These airflow rates shall be considered minimum rates. The measured air balance tolerance for both outdoor air and exhaust air rates shall be -0% to +10%.

K. Include TAB for all kitchen exhaust hoods, fans, make-up air systems, etc. Measure and record airflow, static pressure, and air temperatures at hood exhaust inlets, hood make-up air outlets and hood conditioned air outlets (if applicable).

3.03 WATER SYSTEMS TAB

A. Water circulating systems shall be adjusted and balanced so that water quantities circulated through the apparatus will be as specified.

B. Where no meters are provided, the adjustment of individual coil circuits shall be based on return water temperatures and pressure drops, provided air balancing and adjusting has been satisfactorily completed first. Temperature control valves shall be wide open during the balancing. Balancing cocks and valves shall be set. If this results in excessive total flow, this shall be corrected by partial closing of pump discharge valves during further adjusting and balancing. Settings of cocks, valves, etc. shall be permanently marked so that they can be restored if disturbed at any time.

C. After completion of the testing, adjusting and balancing of the water systems, provide electronic files (e.g. PDFs, etc.) of the complete test report showing the minimum following information which shall be submitted to the Engineer for review:

1. Systems inspection narrative on equipment and installation for conformance with design
2. Systems Readiness Report
3. TAB report covering flow balance and adjustments, performance tests, [vibration tests and sound tests]. Required information:

a. Identification of each piece of apparatus, manufacturer, size, model, rows, etc.
b. Flow as indicated on the Drawings for each piece of apparatus and corresponding pressure drop
c. Temperatures, pressures and corresponding water flow at each coil after each complete system has been balanced and adjusted
d. Head, gpm, bhp, volts, amps for each pump specified
e. Suction and discharge pressures at each pump and corresponding water flow after each complete system has been balanced and adjusted

4. Narrative of uncorrected installation deficiencies noted during TAB and applicable explanatory comments on test results that differ from design requirements.

3.04 MARKING OF SETTINGS AND TEST PORTS

A. Following the approval of the final TAB Report, the setting of all HVAC adjustment devices including valves, splitters and dampers shall be permanently marked by the TAB Specialist so that adjustment can be restored if disturbed at any time. Style and colors used for markings shall be coordinated with the General Contractor.

B. The TAB Specialist shall permanently and legibly identify the location points of duct test ports. If the ductwork has exterior insulation, the identification shall be made on the exterior side of the insulation. All penetrations through ductwork and ductwork insulation shall be sealed to prevent air leaks and maintain integrity of vapor barrier.

END OF SECTION

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SECTION 23 07 00 - HVAC INSULATION

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

B. The insulation shall be installed in a neat and workmanlike manner by trained personnel regularly engaged in the installation of insulation and approved by the insulation manufacturer. Insulation, adhesives, coverings and coatings shall be applied in strict accordance with its respective manufacturer's recommendations. Installer has been in business for no less than 5 years and has completed at least 10 installations of similar size projects.

C. The contractor shall verify that test and inspection of the work to be insulated have been completed and approved before the insulation is applied.

D. All insulation must meet applicable codes for Flame Spread and Smoke Developed ratings when tested in accordance with ASTM 84 and UL 723.

E. VOC Content: Submit adhesive and sealants product information or MSDS showing VOC content information for all applicable products specified under this section. All applicable products in this section must meet low VOC content as specified by LEED Specification Section 01 81 16: Facility Environmental Requirements. All work performed under this specification shall be accomplished in accordance with the requirements and provisions of the following sections:

1.02 WORK INCLUDED

A. The work done under this section shall include all labor, materials, accessories, services and equipment necessary to furnish and install all insulation, complete, as indicated on the Drawings and as specified herein.

1.03 QUALITY ASSURANCE

A. Materials shall be the standard products of manufacturers regularly engaged in the production of insulation products. Insulation materials shall be products that have been in use in commercial buildings for at least 2 years prior to bid opening.

B. Surface Burning Characteristics:

1. Insulation shall have a composite insulation, jacket, binders, and adhesive Flame-Spread rating of 25 or less and a Smoke-Developed rating of 50 or less and shall be so listed by UL.
2. Insulation and related materials shall have surface burning characteristics determined by test performed on identical products per ASTM E 84, NFPA 255, and UL 723, mounted and installed as per ASTM E 2231.

3. Adhesives, mastics, tapes, and other accessories shall have the same component ratings.
4. Materials shall be labeled indicating compliance with the above requirements.
5. All testing shall be performed by a testing and inspecting agency acceptable to authorities having jurisdiction. Insulation, jacket materials, adhesives, mastics, tapes and cement material containers shall be labeled with appropriate markings of applicable testing and inspecting agency.

1.04 RELATED WORK

A. Where pipes and ducts pass through fire walls, fire partitions, above grade floors, and fire rated chase walls, the penetration shall be protected and sealed with fire-stopping materials as specified in Section 23 00 00 - HVAC General.

B. Adequate provisions shall be made to protect the premises, equipment, and the work of other trades against droppings, adhesives and coatings used in the installation.

C. Where indicated, painting of insulation jackets shall be as specified in Section 09 91 00 - Painting.

D. Refer to Section 23 23 00 Refrigerant Piping, Insulation and Accessories for refrigerant piping insulation.

1.05 SUBMITTALS

A. Submit product information for insulation materials to the Architect in accordance with Division 1 and Section 23 00 00 - HVAC General.

B. Submit shop drawings and data to prove complete compliance with these specifications on products and methods of installation. Include materials used, thickness for each application, flame and smoke ratings, thermal conductivity, permeance, density for each product, and jackets (both factory and field applied). Indicate methods of applications.

PART 2 - PRODUCTS

2.01 GENERAL

A. Provide materials which are the standard products of manufacturers regularly engaged in the manufacture of such products and that essentially duplicate items that have been in satisfactory use for at least 2 years prior to purchase. Insulation shall be CFC and HCFC free.

B. Provide insulation that meets or exceed the requirements of ASHRAE 90.1.

C. Insulation exterior shall be cleanable, grease resistant, non-flaking and non-peeling. Materials shall be compatible and shall not contribute to corrosion, soften, or otherwise attack surfaces to which applied in either wet or dry state.

2.02 PIPE INSULATION FOR STEAM AND WATER PIPING

A. Materials as specified in this section shall be manufactured by Armstrong, Johns-Manville, Knauf, Pittsburgh-Corning, CertainTeed, Pabco, Dow Chemical, Owens Corning or approved equal.

B. Insulation thicknesses shall be as shown in the following table:

Minimum Pipe Insulation			Insulation Thickness for Pipe Sizes					
Piping System Types	Fluid Operating Temperature Range		Mean Rating Temp.	Less than 1 in.	1 to less than 1-1/2 in.	1-1/2 to less than 4 in.	4 to less than 8 in.	8 in. and Larger
	°C	°F	°F	In.	In.	In.	In.	In.
(Cooling Systems)								
Chilled Water*, Geothermal Heat Pump Loop, Condensate	4.4-15.6	40-60	75	0.5	1.0	1.0	1.0	1.5
* For chilled water piping located in attics and other unconditioned spaces (excluding return air plenums), increase the pipe insulation thickness by 1/2" for pipe sizes up through 8". Insulation for piping 10" and larger shall be 2-1/2" thick.								

C. Unless noted otherwise, the abovementioned piping systems inside the building shall be insulated with a 5 lb/ft^3 (nominal) density sectional fiberglass insulation with a thermal conductivity (k factor) not to exceed 0.23BTU·in/hr·ft^2·°F (0.033 W/m K), when tested in accordance with ASTM C 335 at 75 °F (24 °C). The jacket shall be fire retardant with a suitable vapor barrier. All joints and seams shall be sealed vapor tight. All joints and seams shall be lapped in place to form a continuous vapor barrier covering. All seams shall then be covered with "All Service Jacket" (ASJ) 3" wide tape. The tape shall match the jacket. The tape shall be squeegeed in place to provide complete adhesion of the tape to the jacket and to provide a continuous vapor barrier covering. Exterior water piping shall be heat traced (Refer to Section 23 21 13 - PIPING AND ACCESSORIES).

D. Piping installed outdoors shall be insulated with cellular glass insulation, Pittsburgh-Corning "Foamglas" or approved equal. Insulation thickness required to prevent condensation shall be determined by the manufacturer for worse case ambient conditions.

1. Install with all service jacket and in accordance with manufacturer's recommendations.
2. Where heat tracing is specified, oversize insulation to allow space for heat tape.

E. Equipment shall be insulated in the same manner as specified for the associated piping. Suitable provisions shall be made for breaking flanges as may be required for maintenance. Hot water pumps do not get insulated unless specifically called for. The following equipment, but not limited to, requires insulation: expansion tanks, air separators, chemical treatment "shot type" feeders, storage tanks, etc.

F. Provide high density preformed pipe insulation inserts at all pipe hangers. Inserts shall be equal to Foamglas by Pittsburgh Corning or calcium silicate. Provide ribbed hanger saddles by Centerline, Buckaroos, Inc. or approved equal.

G. All exposed insulated piping in mechanical rooms below 10'-0" AFF shall be protected by a corrugated aluminum jacket with bands 3'-0" on center.

H. "Circuit setter" type balancing valves shall be insulated with polyisocyanurate or extruded polystyrene block insulation with matching PVC cover. Insulation shall by easily removable for service. Valve insulation shall be as manufactured by Extol or approved equal.

I. Provide insulating tape over all piping specialties to prevent condensation such as drain valves, drain plugs, combination temperature/pressure test plugs, etc.

2.03 BLANKET TYPE INSULATION (DUCTWRAP)

A. Description:

1. Flexible, limited combustible, blanket type insulation composed of mineral or inorganic glass fibers bonded together with a thermosetting resin, meeting ASTM C 553, Type 1 and ASTM C 1290.
2. Vapor retarder jacket: Provide one of the following types of vapor retarder jackets:
   a. Foil-scrim-kraft (FSK), foil reinforced kraft (FRK), or polypropylene-scrim-kraft (PSK) with a 2" (50mm) (min.) stapling and taping flange on one edge.
   b. Conforming to ASTM C 1136 Type II.
3. Surface Temperature Application Limits: Insulation shall be rated for use on surfaces operating at temperatures up to 250°F.
4. Ratings:

Insulation Type:	**Type 1:**	**Type 2:**
Minimum R-Value, out of package*: hr•ft²•°F/Btu (m²•°C/W) at 75°F (24°C) mean temperature	R-7.4 (1.30)	R-10.3 (1.81)
Minimum R-Value, installed: hr•ft²•°F/Btu (m²•°C/W) at 75°F (24°C) mean temperature	R-6.0 (1.06)	R-8.0 (1.46)
Minimum Density: lb/ft³ (kg/m³)	1.0 (16)	0.75 (12)
Thickness: Inches (mm)	2 (51)	3 (76)
Maximum Labeled K-value at 75°F (24°C) mean temperature: Btu.•in/hr.•ft²•°F (W/m.•°C)	0.27 (0.039)	0.29 (0.042)

*Value may vary by manufacturer; minimum installed value must be met

B. Insulate the following with Type 1 blanket insulation:

1. All galvanized steel ductwork containing heated and/or cooled supply air, except:
   a. Exposed ductwork in finished conditioned spaces.
   b. Ductwork indicated to be internally lined or insulated with external insulation.
2. Concealed surfaces of ceiling diffusers exposed to non-return air plenums.
3. Return air ductwork exposed to attics or non-return air plenums.
4. Relief air ductwork and plenums from the exterior to 18" past the relief air damper assembly.
5. Return air, toilet exhaust, and general exhaust ductwork exhausting conditioned air and routed through interior spaces that are ventilated with outside air or exposed to outside air conditions.
6. Concealed outside air ductwork located within indirectly conditioned spaces (e.g. indoor soffits, furr-downs, vertical chases, etc.).
7. Ductwork and plenums located inside of the building (i.e. located within the exterior boundary or skin of the building thermal envelope) when containing or flowing, makeup air, garage ventilation intake or exhaust air ducts and plenums, when not indicated to be insulated with rigid fiberglass insulation. This applies to ducts and plenums whether exposed or concealed within chases when located on the interior side of the exterior skin of heated or cooled space.

C. Insulate the following with Type 2 blanket insulation:

1. Ductwork and plenums located outside of the exterior boundary or skin of the building thermal envelope when containing or flowing heated and/or cooled air when not indicated to be insulated with rigid fiberglass insulation.
2. Supply air ductwork located in unconditioned attic spaces and in indoor spaces that are ventilated with outside air or exposed to outside air conditions.
3. Concealed surfaces of ceiling diffusers exposed to attics.

D. Subject to compliance with requirements, insulation shall be manufactured by: CertainTeed, Johns Manville, Knauf, Owens Corning, or approved equal.

2.04 DUCT LINER

A. Refer to Section 23 31 00 – Ductwork and Accessories for duct liner requirements.

2.05 EXTERIOR SUPPLY AND RETURN AIR DUCTWORK

A. Exterior supply and return air ductwork shall be constructed of galvanized sheet metal lined with 2" thick 3 lb/ft^3 duct liner board (R-2 min); Johns-Manville Linacoustic R-300. All ductwork seams shall be externally sealed watertight with a 30-year silicone caulk and coated with a rust preventive coating over the entire duct surface.

1. As an alternative to insulated sheet metal, an outdoor duct system as manufactured by Thermaduct, LLC may be used. The system shall incorporate duct and fittings having an installed minimum R-value of 12. The system shall utilize non-fibrous closed cell Kingspan KoolDuct fortified inner liner compliant to UL (C-UL) 181,

Standard for Safety Listed, Class 1 system and SMACNA Class 1 leakage, or less. Submit product data and layout drawings during the submittal phase.

2. As an alternative to internal insulation, exterior insulation may be Class B foil faced polyisocyanurate foam insulation with weather resistant white flexible cladding; Alumaguard Lite White by Polyguard. Install in accordance with manufacturer's installation instructions.
3. As an alternative to internal insulation, exterior insulation may be physically crosslinked closed cell polyolefin foam insulation with factory applied heavy duty multilayer composite foil facing with a UV and weather durable coating; Thermobreak No-Clad insulation by Sekisui Voltek. Install in accordance with manufacturer's installation instructions.

2.06 DUCTWORK WITHIN MECHANICAL ROOMS

A. Ducts within mechanical rooms shall be insulated with 1½" thick, 3 lb/ft^3 rigid fiberglass board with an R factor of not less than 6 (K = 0.23 at 75 degrees F mean temperature) with reinforced foil vapor barrier. Insulation shall be secured to ductwork with stick pins and speed washers. All joints and stick pin terminations shall be sealed with 3" wide strips of vapor barrier material and applied to form a continuous vapor seal.

B. Apply 1" x 1" x 30 mils thick white PVC corner angles in accordance with ASTM D 1784, Class 16354-C at all insulation board corners.

2.07 SINGLE WALL BOILER BREECHING AND DIESEL EXHAUST

A. Single wall boiler breeching and diesel exhaust within the building shall be externally insulated with 2" thick calcium silicate block securely held in place with wire or metal bands.

1. As an alternate to field insulated single wall breeching, a factory fabricated insulated double wall pressure stack system may be used. Refer to Section 23 31 00 Ductwork and Accessories for additional information.

2.08 EXTERIOR WEATHER PROTECTION

A. Piping and/or breeching exposed to the weather and designated to be insulated shall be insulated in the same way it is insulated within the building for concealed areas. It shall then be weatherproofed with corrugated aluminum jacketing. It shall have 3/16" corrugations and shall be 0.016" thick with a factory attached moisture barrier continuously laminated across the full width of the jacketing. All pipe fittings, valves and specialties exposed to the weather shall be insulated and weatherproofed with aluminum jacketing. Childers Universe-E11 Jacs of the same metal as the jacketing shall be used. Jacketing shall have a 2" lap at all joints. Longitudinal laps shall be on the underneath side of horizontal runs and slightly offset from one another. The outside of the longitudinal lap shall also have a 1" hem turned under. All laps shall be made with weatherproof mastic. Wrap the jacketing tightly and smoothly and secure with aluminum or stainless steel bands. Bands shall not be more than 12" on center and a strap shall be placed at the circumferential

laps. The lap shall have adequate mastic to make a tight joint. Excess mastic shall be removed from the outside to provide a neat and professional appearance.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Shop drawing submittals shall include a complete package of materials and methods intended for use as described in this section.

B. All work shall be in strict accordance with applicable codes, ordinances and the manufacturer's recommendations.

C. All work shall be performed in a professional workmanlike manner and standard trade practice. It shall be smooth in appearance and suitable for finish painting.

D. All exterior piping shall be installed with a corrugated aluminum jacket with bands 3'-0" on center.

E. Provide insulating tape over all piping specialties to prevent condensation such as drain valves, drain plugs, combination temperature/pressure test plugs, etc.

F. Fiberglass pipe insulation shall be applied to clean (free of rust) dry pipe prior to leak testing. Chilled and condenser water systems shall not be operated until the insulation is completely installed with a vapor barrier in place. Refer to Section 23 21 13 - Piping and Accessories for additional information.

END OF SECTION

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SECTION 23 07 14 - FIRE-RATED INSULATION SYSTEMS

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

B. The insulation shall be installed in a neat and workmanlike manner by experienced personnel regularly engaged in the installation of insulation and approved by the insulation manufacturer. Insulation, adhesives, coverings and coatings shall be applied in strict accordance with its respective manufacturer's recommendations. The installer shall have been in business for no less than 5 years and completed at least 10 installations of similar size projects.

C. The contractor shall verify that testing and inspection of the work to be insulated has been completed and approved before the insulation is applied.

D. All insulation must meet applicable codes for Flame Spread and Smoke Developed ratings when tested in accordance with ASTM 84 and UL 723.

1.02 WORK INCLUDED

A. The work done under this section shall include all labor, materials, accessories, services and equipment necessary to furnish and install all insulation, complete, as indicated on the Drawings and as specified herein.

B. Systems include:

1. Plenum wrap insulation to achieve a non-combustible rating for combustible materials in an air plenum.
2. Duct insulation to achieve zero clearance to combustibles and a 2-hour fire-resistive rated duct enclosure on commercial kitchen grease duct exhaust systems.

1.03 REFERENCES

A. The following published specifications, standards, tests, or recommended methods of trade, industry, or governmental organizations apply to single layer noncombustible fire rated plenum insulation:

1. UL 1887 - Visible Flame and Smoke Characteristics for Plastic Pipe.
2. ASTM E 84/UL/ULC 723 - Surface Burning Characteristics.
3. ASTM E 136 - Non-combustibility.

B. The following published specifications, standards, or tests apply to zero clearance two-layer fire rated systems of grease duct insulation:

1. NFPA 96
2. International Code Council Evaluation Service (ICCES)

3. ASTM E 2336 - Standard Test Methods for Fire Resistance Rated Grease Duct Enclosures
4. CAN/ULC-S144-09 Standard Method of Fire Resistance Test - Grease Duct Assemblies First Edition
5. ASTM E 84 - Standard Test Method for Surface Burning Characteristics of Building Materials
6. ASTM E 119 - Standard Test Methods for Fire Tests of Building Construction and Materials
7. ASTM E 136 - Standard Test Method for Noncombustiblity
8. ASTM E 518 - Standard Test for Durability
9. ASTM E 814 - Standard Test Method for Fire Tests of Through-Penetration Fire Stops

1.04 QUALITY ASSURANCE

A. Materials shall be the standard products of manufacturers regularly engaged in the production of insulation products. Insulation materials shall be products that have been in use in commercial buildings for at least 5-years prior to bid opening.

B. Fabricator Qualifications: Fabrication performed in quality-controlled manufacturing environment by experienced fabricators with references indicating multiple successful projects fabricating high temperature insulation blanket as required for this project.

C. Installer Qualifications: Installers experienced in performing work of this section who have specialized in installation of work similar to the scope required for this project.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials in original unopened packages, clearly marked with manufacturer's name, product designation, manufacturer's lot numbers and appropriate third-party classification listings.

B. Store in a covered dry environment.

C. Store and dispose of solvent-based materials, and materials used with solvent-based materials, in accordance with requirements of local authorities having jurisdiction.

1.06 PROJECT CONDITIONS

A. Maintain environmental conditions (temperature, humidity, and ventilation) within limits recommended by the manufacturer for optimum results. Do not install products under environmental conditions outside of manufacturer's absolute limits.

1.07 SUBMITTALS

A. Submit product information for insulation materials to the Architect in accordance with Division 1 and Section 23 00 00 - HVAC General.

B. Submit shop drawings and data to prove complete compliance with these specifications on products and methods of installation. Include materials used, thickness for each

application, flame and smoke ratings, thermal conductivity, permeance, density for each product, and jackets (both factory and field applied), if any. Indicate methods of application.

C. Submittal shall include storage and handling requirements and recommendations.

D. Submit certification and installation documentation showing system performance and code compliance.

1.08 MANUFACTURERS

A. Basis of design manufacturer: Unifrax I, LLC. Equal manufacturers provided they conform with the contract documents: 3M Fire Barrier and Morgan Thermal Ceramics Firemaster.

B. Manufacturers other than the basis of design manufacturer shall include a Compliance Review of the Specifications and Addenda (if applicable). The Compliance Review shall be a paragraph-by-paragraph review of the Specifications with the following designations marked in the margin of the original Specifications and any subsequent Addenda:

1. "C": Complies with no exceptions.
2. "D": Complies with deviations. For each and every deviation, provide a numbered footnote with reasons for the proposed deviation and how the intent of the Specification will be satisfied.
3. "E": Exception, does not comply. For each and every exception, provide a numbered footnote with reasons for non-compliance and possible alternatives.

PART 2 - PRODUCTS

2.01 PLENUM INSULATION FOR NONCOMBUSTIBLE FIRE RATED PLENUM

A. Product: FyreWrap 0.5 Plenum Insulation by Unifrax I, LLC, Tonawanda, NY:

1. Nominal 0.5 inches (12 mm) thick foil encapsulated blanket material at 8 lbs/ft^3 to provide a non-combustible rating.
2. An inorganic, flexible, non-asbestos, bio-soluble high temperature, foil encapsulated blanket material.
3. Blanket insulation shall maintain a 2012ºF (1100ºC) operating temperature
4. Blanket fiber materials shall be tested per EU regulatory requirements, Directive 97/69/EC for bio-solubility, and verified by an independent laboratory.
5. Performance: A lightweight, non-asbestos, bio-soluble, high temperature, inorganic, foil encapsulated insulation blanket. The plenum insulation system shall be tested and listed to provide a non-combustible rating for combustible items located in air plenums.
   a. Performance Requirements:
      1) Single Layer System of 1/2 inch (13 mm) thick material
      2) Meets UL 1887 test criteria for visible flame and smoke characteristics.
      3) Meets 25/50 Flame and Smoke Ratings per ASTM E 84.
      4) Insulation and combustible item shall be tested as an assembly.

5) Tested and listed for PVC, CPVC, PB, PE, PP, PVDF and ABS.

2.02 DUCT INSULATION FOR ZERO CLEARANCE FIRE-RATED GREASE DUCTS

A. Product: FyreWrap Elite 1.5 Duct Insulation by Unifrax I, LLC, Tonawanda, NY:

1. Nominal 1.5 inch (38 mm) thick foil encapsulated blanket material at 6 lbs/ft^3 to provide 2-hour fire resistive enclosure assembly per ASTM E 2336.
2. A lightweight, flexible, inorganic, non-asbestos, bio-soluble, high temperature, foil encapsulated blanket wrap.
3. Flexible, fully encapsulated blanket material, two-layer system to provide 2-hour fire resistive enclosure assembly per ASTM E 2336 and CAN/ULC-S144-09.
4. Blanket insulation shall maintain a 2012ºF (1100ºC) operating temperature.
5. Blanket fiber materials shall be tested per EU regulatory requirements, Directive 97/69/EC for bio-solubility, and verified by an independent laboratory.
6. Provide field fabricated or prefabricated fire rated access doors (for cleanouts as required) to maintain 2-hour rating and required clearance.
7. Provide firestop sealants, tape, insulation pins, clips, banding and other components per manufacturer's installation instructions to provide fully functioning zero clearance to combustibles grease duct system.
8. Performance: Lightweight, non-asbestos, bio-soluble, high temperature, inorganic, foil encapsulated insulation blanket. The blanket material shall be capable of performing at 2000ºF (1093ºC) matching the internal and external fire test temperature for grease ducts. The duct wrap system shall be a tested and listed system evaluated for reduced clearances to combustibles as an alternative to a grease duct, with a two-hour fire rated shaft enclosure. Testing shall be conducted at a nationally recognized testing laboratory.
   a. Performance Requirements:
      1) Two-layer system of 1½ inch (38 mm) 6 lbs/ft^3 (96 kg/m3) material
      2) Zero clearance to combustibles across the entire surface of the blanket material per internal fire tests of ASTM E 2336
      3) 2-hour fire resistive enclosure assembly per ASTM E 119
      4) CAN/ULC-S144-09: Stability-2hr, Integrity-2hr, Insulation-2hr
      5) Firestop tested per ASTM E 814, 2 Hour F and T Ratings
      6) Meets 25/50 flame and smoke ratings per ASTM E 84

2.05 ACCESS DOORS

A. Access Door: Field fabricated 16-gauge steel

1. Threaded Rods: ¼ inch (6 mm) diameter
2. Gasket: ½ inch (13 mm) Unfaced FyreWrap or ceramic fiber blanket

B. Access Door: Ductmate Ultimate prefabricated 16-gauge steel

C. Access Door: Ductmate F2 prefabricated 16-gauge steel

PART 3 – EXECUTION

3.01 GENERAL

A. Shop drawing submittals shall include a complete package of materials and methods intended for use as described in this section. Include installation instructions, UL details, Material Data Safety Sheets, etc.

3.02 EXAMINATION

A. Do not begin installation until substrates have been properly prepared.

B. If substrate preparation is the responsibility of another installer, notify Architect of unsatisfactory preparation before proceeding.

3.03 PREPARATION

A. Inspect and verify that all surfaces are smooth, dry, clean and free from dust, debris, or other loose materials. Surfaces shall be dry before the application of insulation materials.

B. Clean surfaces thoroughly prior to installation.

C. Prepare surfaces using the methods recommended by the manufacturer for achieving the best result for the substrate under the project conditions.

3.04 INSTALLATION

A. All work shall be in strict accordance with applicable codes, ordinances and the manufacturer’s installation instructions.

B. All work shall be performed in a professional workmanlike manner and standard trade practice. The finished work shall be smooth in appearance and suitable for finish painting.

3.05 FIELD QUALITY CONTROL

A. The manufacturer shall visit the project site to review the work and report in writing any deficiencies to the installing contractor. The report shall include recommendations for corrective action.

B. Schedule site visits to review the work during the preconstruction meeting.

3.06 PROTECTION OF THE WORK

A. Protect installed products until completion of project.

B. Touch-up, repair or replace damaged products prior to Substantial Completion.

END OF SECTION

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SECTION 23 09 00.10 - BUILDING AUTOMATION SYSTEM

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

B. It is the intent of this specification to describe the basic architecture and performance requirements of the Building Automation System (BAS). The turn-key BAS shall include all software including operator software, programming tools, graphics editor, all other available software programs, modules, or plug-ins offered by the DDC manufacturers, hardware, Control Units, Distributed Controllers, Unitary Controllers, Local Area Networks (LANs), sensors, modems, wiring, connectors, control devices, actuators, installation and calibration, supervision, adjustments and fine tuning necessary for a complete and fully operational system. The BAS application program shall be written to communicate specifically utilizing BACnet protocols. Software shall include password protection, alarming, logging of historical data, full graphics including animation, full suite of field engineering tools including graphical programming and applications. All software including user interface, technician tools, programming tools, and graphic tools shall not require licensing subscriptions. If subscriptions are required, the BAS provider shall include 10 years of subscription services.

C. A distributed Direct Digital Control (DDC) 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. 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.

D. All systems shall be complete true standalone OPEN systems.

E. The BAS must be an OPEN system. An open system is defined as a system that used industry standard protocols such as BACnet, Modbus, or LonWorks. The BAS shall provide the owner with all the tools necessary to make any modifications to the system without the requirement of a technician from the BAS provider.

F. Everything shall be reprogrammed through software without change of any hardware. The owner shall have all the tools necessary to reprogram without any additional costs.

G. The BAS shall have backward and forward compatibility.

H. All equipment, labor, tubing, etc. required to accomplish the control sequences outlined on the Drawings and in this Section, shall be furnished as part of the HVAC work.

I. All field-level controllers and end devices shall be provided and installed by the controls contractor under this specification section.

J. All other HVAC equipment purchased and installed as described in other sections of these specifications shall be coordinated with the requirements of this section to assure compatibility and function.

K. All electrical control wiring required as part of this work shall be furnished and installed as part of the HVAC work and shall be installed in accordance with Division 26.

L. This section generally describes the desired operating sequence and characteristics of all HVAC systems provided and installed as part of Division 23 of these specifications. The preparation of the detailed control schematics necessary to accomplish the desired systems operation shall be included as part of the HVAC work. Electronic copies of these control schematics in PDF format shall be submitted and reviewed by the Engineer as part of the Submittal phase prior to the purchase or installation of any control equipment or other equipment that depends on these control schemes for proper operation.

M. Mount top of thermostats and sensors at 46" AFF unless noted otherwise. Provide clear locking guard assemblies for all public area thermostats. Coordinate thermostat locations with all trades. Coordinate final locations with the general contractor, interior designer, and the owner prior to installation. Locate adjacent to light switches where possible. Do not locate thermostats at the center or near center of a wall. Thermostats shall be mounted no closer than 8" from the corner or end of a wall or door. All thermostats shall be ADA compliant.

N. All major control equipment shall be located in suitable enclosures; NEMA 1 for indoor installations and NEMA 3R for outdoor installations.

1.02 CODES AND REFERENCES

A. Workmanship, materials, and equipment together with the resultant complete and operational DDC system shall be in compliance with the Authorities Having Jurisdiction (AHJ) for the project and the most restrictive of applicable local, state and federal codes and ordinances in cooperation with these plans and specifications. This contractor shall secure and pay for all applicable costs, fees, permits, and licenses. No additional costs shall be allowed for these items. At a minimum, the installation shall comply with the applicable sections of the current editions in effect thirty (30) days prior to receipt of bids of the following codes and standards:

1. ANSI/ASHRAE Standard 135 – BACnet-A Data Communication Protocol for Building Automation and Control Networks
2. Additional ASHRAE Standards
3. FCC-Part 15 Subparagraph J Class A Emissions Requirements
4. National Fire Protection Association – 70, 90A, 90B, 92
5. Underwriters Laboratories (UL) – UL-916 – Energy Management Systems (EMS)
6. Underwriters Laboratories (UL) – UL-864 – Standard for Control Units and Accessories for Fire Alarm Systems/UUKL Smoke Control System Equipment
7. IEEE802.11a/b/g/n
8. IEEE802.11n HT20 @ 2.4GHz
9. IEEE802.11n HT20/HT40 @ 5GHz

1.03 SPECIFICATION NOMENCLATURE

A. BAS: Building Automation System

B. BTL: BACnet Testing Laboratories

C. DDC: Direct Digital Control

D. I/O: Input/Output

E. LAN: Local Area Network

F. MS/″TP: Master Slave / Token Passing

G. O&M: Operation and Maintenance

H. OWS: Operator Workstation

I. NC: Normally Closed

J. NO: Normally Open

K. PC: Personal Computer

L. PID: Proportional plus Integral plus Derivative

M. RTD: Resistance Temperature Detector

N. SPDT: Single Pole Double Throw

O. WAN: Wide Area Network

P. WIFI: IEE802.11 a/b/g/n

1.04 MANUFACTURERS

A. Acceptable manufacturers/installers for automatic controls: Distech Controls, Honeywell WEBs, Johnson Controls, Inc. Facility Explorer, Automated Logic WebCTRL.

B. Manufacturer shall meet the performance and material specifications of a product or component.

C. Available manufacturer listing does not grant permission of a manufacturer to deviate from this specification.

D. Installed systems must be OPEN as referenced in Section 1.01.E and 1.01.F. The owner shall have the ability to modify, service, or expand the system without the need of a technician from the BAS provider.

1.05 SYSTEM PERFORMANCE

A. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for web browser interface:

1. Configuration and Tuning Screens: Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.
2. 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.
3. Object Scan: Transmit change of state and change of analog values to control units or workstation within six seconds.
4. Alarm Response Time: An object that goes into alarm shall be annunciated at the workstation within 15 sec. Each workstation on the network shall receive alarms within five seconds of each other.
5. 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.
6. 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.
7. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
    a. Water Temperature: Plus or minus 1°F.
    b. Water Flow: Plus or minus 5 percent of full scale.
    c. Water Pressure: Plus or minus 2 percent of full scale.
    d. Space Temperature: Plus or minus 1°F.
    e. Ducted Air Temperature: Plus or minus 1°F.
    f. Outside Air Temperature: Plus or minus 2°F.
    g. Dew Point Temperature: Plus or minus 3°F.
    h. Temperature Differential: Plus or minus 0.25°F.
    i. Relative Humidity: Plus or minus 2 percent
    j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
    k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
    l. Airflow (Terminal): Plus or minus 10 percent of full scale.
    m. Air Pressure (Space): Plus or minus 0.01-inch wg.
    n. Air Pressure (Ducts): Plus or minus 0.1-inch wg.
    o. Electrical: Plus or minus 5 percent of reading.

1.06 WORK INCLUDED

A. Furnish, install, program, and place into operation the BAS as specified herein and as shown on the drawings.

B. Furnish all input and output (I/O) control and accessory components as required to provide a complete workable system.

1. The control system shall also incorporate mechanical/electrical automatic temperature control devices, enclosures, interconnecting conduit, and cabling.
2. The BACnet® operating stack must be embedded directly in each individual DDC device at the media access controller level and in all operator interface and configuration applications. All hardware must be BTL listed.
3. All building controllers, application controllers, unitary controllers, and all input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135-2008, BACnet®.
4. Communication gateways, bridges, protocol translators or any other device that translates any proprietary communication protocol to BACnet® shall not be permitted as a part of the DDC system provided pursuant with this specification except as required to communicate to existing building systems or to systems installed under other sections. No gateways shall be used for communication to controllers installed under this section.

C. General: The control system shall consist of a high-speed, peer-to-peer network of ANSI/ASHRAE 135 native BACnet® DDC devices (DDC controllers and a web-based operator interface) for building mechanical and electrical systems. Depict each mechanical system and building floor plan by point-and-click graphics. Web pages shall be accessible through a conventional web browser. Operators shall be able to perform all normal operator functions through the web browser interface.

1. Equipment graphics shall be animated displaying all point data from the sequence of operations.
2. Equipment shall have the ability to be scheduled for normal, weekend, holiday, and events.
3. Remote alarm notification shall be via email and text messaging.

D. The Owner will provide IP addresses and any other network configuration information necessary to each control contractor for the purpose of configuring each Area Controller on the network. The controls contractor shall coordinate the IP address for each Area Controller. It shall be the responsibility of the control contractor to coordinate with the owner for network connectivity.

E. The system shall directly control HVAC equipment as specified in the Contract Documents. Each zone controller shall provide occupied and unoccupied modes of operation by individual zone. Furnish energy conservation features such as optimal start and stop, lighting control, night setback, request-based logic, and demand level adjustment of set points.

F. System shall use the BACnet® protocol for communication. Schedules, set points, trends, and alarms specified in the Sequences of Operation shall be BACnet® objects.

G. Design and provide all equipment cabinets, panels, data communication network cables needed, and all associated hardware.

H. Provide all interconnecting cables between supplied cabinets, application controllers, and input/output devices.

I. Provide complete manufacturer's specifications for all items that are supplied. Include vendor name of every item supplied.

J. Provide supervisory specialists and technicians at the job site to assist in all phases of system installation, startup, and commissioning.

K. Provide protective devices to prevent damage to the BAS as a result of lightning.

L. The BAS shall allow full user operation with a minimum of training. It shall have an English language display, with both user prompts and a "help" user tutorial.

M. The bidder shall perform sufficient site investigations to include all requirements described in the construction documents. Bids shall include, at Bidder's discretion, costs related to site verifications for renovation projects. No additional costs shall be allowed for such items.

N. Contractor shall have an obligation to participate in, cooperate with and support the Commissioning Agent process. Support includes, but is not limited to, tools, equipment, and personnel. Reference Division 23 Commissioning of HVAC. The Contractor shall conduct a coordination meeting with the BAS installer, commissioning agent, and design engineer prior to the submittals being prepared. The purpose of the meeting will be to qualify Sequences of Operation and determine what Cx procedures will be implemented.

O. Communications with Third Party Equipment: Control systems included with the products to be integrated with the work of this section shall be furnished with a network card (IP) for status and monitoring for BACnet® or Modbus over IP interface into the Direct Digital Control System described in this section (reference sequence of operations and points list for specifics). Those systems include Boilers, Chillers, CRAC units, Energy Recovery Units, Airflow Monitoring, Lighting, Power Monitoring, Switchgear, Fire Detection, Utility Sub-Meters, Variable Frequency Drives, and/or Variable Refrigerant Flow systems.

P. Prices shall be adhered to in all additional services and changes during project construction and throughout the warranty period.

Q. All controller hardware shall have a 2-year manufacturer's warranty. Warranty to include parts and labor. Warranty shall also include installation of all current software/firmware upgrades/patches available at the end of the warranty period.

R. Provide cost for service agreement along with details of service for three (3) years after the end of the warranty period. Contract agreement and cost should not be included in this project but should be provided separately to the Owner. A customer service plan shall be provided to the Owner and with a detailed description of agreement and rates. Service agreement shall include the following:

1. Discount on service labor rates
2. Guaranteed service response time of dial-in modem support within two (2) business hours, onsite service within six (6) business hours, and emergency repair service within two (2) hours when required at an additional cost.

3. Priority telephone assistance
4. Quarterly service for the following:
   a. Review of system operation
   b. Service maintenance for host computer workstation, controllers taps/modems, temperature and humidity calibration, power fail restart sequences, DDC controllers, and access controllers and door hardware.
5. Service summary reports to Owner Data base protection
6. Software upgrades

1.07 QUALITY ASSURANCE

A. The DDC system manufacturer shall be engaged full-time in the manufacture of equipment and devices of the scope, size and service required.

B. The DDC system manufacturer shall operate a Quality Management System formally certified to be in compliance with ISO 9001:2015.

C. The BAS shall provide the owner with all the tools necessary to make any modifications to the system without the requirement of a technician from the BAS provider.

D. Installer qualifications: Automatic control system manufacturer's officially authorized representative who is trained and approved for installation of system components required for this Project.

E. Installer shall have an established working relationship with the Control System Manufacturer for a period of 5 years or greater. If the distributorship has not had a duration of more than 5 years, the contractor will not be approved without written approval prior to bid date (no exceptions).

F. The DDC system Contractor shall assign project technicians and engineers who are officially trained and certified by the DDC System Manufacturer in the design, installation, programming and operation of the DDC System components.

G. The BAS installer shall have all tools, testing, and calibration equipment necessary to ensure reliability and accuracy of the system.

H. 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.

I. The DDC BACnet® network shall be based upon and installed according to the DDC System Manufacturer's standard integrated hardware and software product design and in accordance with the Manufacturer's installation and application documentation.

J. Comply with ASHRAE/ANSI 135 (Data Communication Protocol for Building Automation and Control Systems {BACnet}) for DDC system components.

K. Maximum reliability shall be achieved through extensive use of high-quality, pre-tested components. Each and every controller, sensor, and all other DDC components shall be individually tested by the manufacturer prior to shipment.

L. Provide all necessary BACnet-compliant hardware and software to meet the system's functional specifications. Provide Protocol Implementation Conformance Statement (PICS) for every controller in the system, including unitary controllers.

M. The software shall provide the ability to view the logic in a monitor mode. When on-line, the monitor mode shall provide the ability to view the logic in real time for easy diagnosis of the logic execution. When off-line (debug), the monitor mode shall allow the user to set values to inputs and monitor the logic for diagnosing execution before it is applied to the system. All programming shall be done in real-time. Systems requiring the uploading, editing, and downloading of database objects shall not be allowed.

N. Engineer shall reserve all authority regarding approval, conditional approval, or rejection of systems not fully complying with these specifications.

1.08 SUBMITTALS

A. Product Data and Shop Drawings: 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. es on suitable solid-state media (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, 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) Transducers and transmitters
      3) Sensors (including accuracy data)
      4) Actuators
      5) Valves
      6) Relays and switches
      7) Control panels
      8) Power supplies
      9) Batteries
      10) Operator interface equipment

11) Wiring

c. Wiring diagrams and layouts for each control panel. Show termination numbers.

a. 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.

b. Riser diagrams showing control network layout, communication protocol, and wire types.

c. Include list of control valves, Cv, pressure drops, spring ranges including actuator action (i.e., fail position, two-position, fail open/in place/close, etc.).

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 – web server
8) Color graphic software

B. Provide complete description and documentation of any proprietary (non-BACnet) services and/or objects used in the system.

C. 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. Bill of materials of equipment indicating quantity, manufacturer, and model number.
2. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
3. Wiring Diagrams: Power, signal, and control wiring. Include equipment interlocks of affected systems and equipment, including chillers, pumps, exhaust fans, etc.
4. Control diagrams shall also indicate panels, gauges, control components, spring ranges, and set points.
5. Details of control panel faces, including controls, instruments, and labeling.
6. Written description of sequence of operation for each system.
7. Schedule of dampers including size, leakage, and flow characteristics including actuator action (i.e., fail position, two-position, fail open/in place/close, etc.).
8. Schedule of valves including flow characteristics.
9. DDC System Hardware:

a. Wiring diagrams for control units with termination numbers.
b. Schematic diagrams and floor plans for field sensors and control hardware.
c. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between Network Area Controller and control unit.

10. Control System Software:
    a. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
    b. 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.
    c. List of color graphics indicating monitored systems, data (connected and calculated) point addresses, output schedule, and operator notations.
11. Controlled Systems:
    a. Schematic diagrams of each controlled system with control points labeled and control elements graphically shown, with wiring.
    b. Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.
    c. Written description of sequence of operation including schematic diagram.
    d. Points list.

D. Data Communications Protocol Certificates: Certify that each proposed DDC system component complies with Open Protocol native BACnet.

E. Project Record Documents: Submit electronic copies of record (as-built) documents upon completion of installation for approval prior to final completion. Submittal shall consist of:

1. Project Record Drawings. As-built versions of submittal shop drawings provided in Visio or ACAD format.

F. Operation and Maintenance (O&M) Manual. In addition to items specified in Division 01 Section "Operation and Maintenance Data," include printed, electronic, or online help documentation of the following:

1. As-built versions of submittal product data.
2. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
3. Qualification data: for installer and manufacturer. Reference Section 1.07 on Quality Assurance.
4. Operator's manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, override control, and changing setpoints and variables.
5. 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.

6. 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.
7. 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.
8. Graphic files, programs, and database on optical media or electronic PDF.
9. List of recommended spare parts with part numbers and suppliers.
10. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
11. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
12. Licenses, guarantees, and warranty documents for equipment and systems.
13. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection period, cleaning methods and materials recommended, and calibration; time between tasks; and task descriptions.
14. Calibration records and list of setpoints.
15. Field quality-control test reports.

G. Online As-Builts – Contractor shall provide digital replications of as-builts that shall be accessible from equipment graphic locations for each piece of mechanical or electrical equipment controlled or monitored by the BAS.

H. Training Materials: The contractor shall provide training to owner personnel at the project site. Each student shall be provided with a dedicated computer workstation utilizing a simulated BAS software platform that is installed for this project. The owner shall not incur any additional cost for training classes as listed below for the first 3 years.

1. Provide training for a designated staff of Owner's representatives. Training shall be provided on site by a factory trained instructor and experienced in presenting material.
2. Provide course outline and materials for each class at least six weeks before first class. Training shall be furnished via instructor-led sessions. 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.
3. Training shall be provided as follows:
   a. Eight Hours furnished before project is turned over to owner.
   b. Eight hours furnished with in three months of project turnover to owner.
   c. Sixteen hours to be used in minimum four blocks at owner's discretion within 12 months from project turnover to owner.

I. The following training courses shall be conducted for 4 individuals on 4 separate occasions each year for a 3-year period (12 classes total) following substantial completion:

1. Operator Overview - Consists of general system navigation, scheduling functions, setpoint modifications and parameter adjustments.
2. Advanced Topics Overview – How to manage users and access level users are to be granted; detailed analysis of trend setup/configuration, trend historian, alarm setup, alarm actions (email, printing, etc.), point renaming, and detailed analysis of equipment parameters.
3. Program/Logic Manipulation - Modify system programs as needed for additions and modifications.
4. Graphic Manipulation - Modify system graphics as needed for additions and modifications.
5. Hardware Troubleshooting - Operators shall be able to interact with this live system through the BAS utilized for this project. Class will provide students the ability to identify and repair common problems regularly encountered.
6. Software Troubleshooting - Operators shall be able to interact with this live system through the BAS utilized for this project. Class will provide students the ability to identify and repair common issues that can be utilized via software modifications.
7. HVAC System Training - Objective of this class is to provide basic HVAC system knowledge of systems on this project. This includes basic principle of the air side systems including VAV air systems, economizer control, dehumidification, demand control ventilation, as well as, water side distribution systems such as pumping type (variable or constant), system type (primary/secondary or variable primary), and economizer control.

J. Software and Firmware Operational Documentation: Include the following:

1. Software operating and upgrade manuals.
2. Program Software Backup: On a flash drive, complete with data files.
3. Device address list.
4. Software license required by and installed for any DDC workstations and control systems.

1.09 DELIVERY, STORAGE, AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.

1.10 COORDINATION

A. All equipment, components, parts, materials, etc. provided throughout the period of Work shall be fully compatible with all other equipment, etc. provided at any other time throughout the period of Work. Should updated versions of equipment be provided which are not fully compatible with earlier equipment provided, Contractor shall replace earlier equipment with later version at no cost to the Owner.

B. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans (i.e. Architectural and Interior Design) and room details before installation.

C. Coordinate compatibility of installed equipment with Division 26 Section “Network Lighting Controls”.

D. Coordinate compatibility of installed equipment with Division 28 Section “Fire Detection and Alarm”.

E. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.

F. Coordinate equipment with Division 22 for gas meters, water meters, sump pump high level alarms, oil minder detection for elevator sumps, pump failures, diesel fuel tank monitoring, diesel fuel transfer pump monitoring, and any other plumbing equipment requiring monitoring to achieve compatibility of communication interfaces.

G. Coordinate equipment with Division 26 Section “Electrical Power Monitoring and Control” to achieve compatibility of communication interfaces.

H. Coordinate equipment with Division 26 Section “Panelboards” to achieve compatibility with starter coils and annunciation devices.

I. Coordinate equipment with Division 26 Section “Motor-Control Centers” to achieve compatibility with motor starters and annunciation devices.

1.11 WARRANTY

A. Warrant work as follows:

1. Warrant materials for specified control system and peripheral control devices free from defects for a period of two (2) years after final acceptance. Warrant all labor for a period of two (2) years 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. During the warranty period, the BAS contractor shall respond to calls for warranty service within eight (8) working hours. Emergency service shall be obtainable within four (4) hours of notification by the Owner. Emergency service shall be obtainable on a 24-hour basis, seven (7) days per week. Additionally, Contractor shall offer 24/7 after-hours support to include alarm monitoring and associated dispatch service.
2. The BAS contractor’s office shall be within a 150-mile radius of the job site.
3. The BAS contractor shall obtain final approval from the owner on requirements for graphics before graphics are installed. This includes what points to display on each graphic, equipment tagging, and how graphics are organized.
4. The BAS contractor shall obtain final room number requirements from the owner prior to creating floor plan graphics.

B. The Owner shall grant to the Contractor, reasonable access to the BAS system during the warranty period including VPN access rights. The owner shall provide, at no cost to the contractor, a remotely accessible Ethernet connection during this period. Access shall have all features as if directly connected to the DDC system. Provide an engineering password for access to system and training as noted in the training section of this document. The

contractor shall have remote access via Internet to the entire facility control system to provide service and diagnostic support.

C. 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.

1.12 OWNERSHIP OF PROPRIETARY MATERIALS

A. Project-specific software and documentation shall become the Owner's property. This includes, but is not limited to: Application Programming Code, Database, Documentation, Graphics, and Record Drawings.

PART 2 - PRODUCTS

2.01 SUPPLIER QUALIFICATIONS

A. The Building Automation System (BAS) system integrator shall be a local or factory authorized office staffed with factory trained engineers and system representatives fully capable of providing instruction, routine maintenance, and emergency maintenance service on all system components. The BAS system integrator and installation team shall have a minimum of 10-years' experience in the design and installation of BASs similar in scope and size to that specified herein and shall be prepared to provide evidence of this history. The BAS system integrator shall have no less than three (3) similar projects which have BACnet-based building systems as specified herein installed by the authorized representative. These projects must be on-line and functional such that the Owners/Users representative can observe the system in full operation.

B. The contractor shall use only thoroughly trained and experienced workmen completely familiar with the items required and with the manufacturers recommended methods of installation. In all respects, the workmanship shall be of the highest grade, and all construction shall be done according to the best practice of the trade. Conduit shall be provided as required by Division 26, except that metal-clad (MC) armored cable shall not be allowed. Unless otherwise noted, conduit shall be concealed and installed square to the building lines. Any work not meeting these requirements shall be replaced or rebuilt without extra expense to the Owner.

C. As part of the routine and emergency maintenance service on system components during the installation, acceptance and warranty periods specified herein, the BAS system integrator shall have documented proof of resident factory trained maintenance/service personnel in all areas/scope of this system.

2.02 GENERAL

A. Only those products of particular importance to appearance or function are described in this Products section. Other items required for satisfactory systems operation but not herein described shall be furnished and installed to meet the intent and Operating Sequences herein described.

B. All materials and equipment used shall be standard components, of regular manufacture for this application. All systems and components shall have been thoroughly tested and

proven in actual use.

2.03 MATERIALS

A. Provide new products the manufacturer is currently manufacturing and selling for use in new installations. New products shall be from a single manufacturer where possible with substitutions approved by the Engineer/Owner. Do not use this installation as a product test site unless explicitly approved in writing by the Owner. Spare parts shall be available for at least the duration of the warranty period as a minimum.

B. Installed devices shall be BTL listed.

2.04 GRAPHICAL USER INTERFACE COMPUTER HARDWARE (LAPTOP COMPUTER)

A. The computer hardware requirements are primarily controlled by the BAS provider and shall consist of an Intel Core i5 or i7 with provisions for an Ethernet connection and to connect a printer. The processing speed, RAM, and hard drive capacity shall be confirmed with the software manufacturer/provider and operating system.

B. Connection to the BAS network shall be via an Ethernet network interface card.

2.05 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet® network. Controller and operator interface communication shall conform to ASHRAE/ANSI Standard 135.

B. Web server and controllers shall communicate using BACnet protocol. Web server 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. Communication between the web server and client (workstation) shall be HTTP or HTTPS protocol utilizing HTML5 language. Use of Adobe Flash in any part of the communication infrastructure is not acceptable.

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. Network 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 network controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each network controller.
2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the network. Program and test all cross-controller links required to execute control strategies specified in

Contract Documents. 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. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. System shall automatically adjust for daylight saving and standard time.

F. System shall have the capability of being expandable to at least 1.5 times the required input and output objects with additional controllers, associated devices, and wiring. Confirm exact system requirements with the Owner prior to final pricing and installation.

G. System shall support Web services data exchange with any other system that complies with XML (extensible markup language) and SOAP (simple object access protocol) standards. Web services support shall as a minimum be provided at the workstation or web server level and shall enable data to be read from or written to the system.

1. System shall support Web services read data requests by retrieving requested trend data or point values (I/O hardware points, analog value software points, or binary value software points) from any system controller or from the trend history database.
2. System shall support Web services write data request to each analog and binary object that can be edited through the system operator interface by downloading a numeric value to the specified object.
3. For read or write requests, the system shall require username and password authentication and shall support SSL (Secure Socket Layer) or equivalent data encryption.
4. System shall support discovery through a Web services connection or shall provide a tool available through the Operator Interface that will reveal the path/identifier needed to allow a third-party Web services device to read data from or write data to any object in the system which supports this service.
5. Direct access to trend data shall be provided in order to facilitate historical information stored by the system.

2.06 SOFTWARE LICENSE AGREEMENT

A. The BAS contractor shall sign a copy of the manufacturer's standard software and firmware licensing agreement as a condition of this contract. Such license shall grant use of all programs and application software as defined by the manufacturer's license agreement but shall protect the manufacturer's rights to disclosure of trade secrets contained within such software.

B. The open license must contain the following statements:

1. accept.station.in="*"
2. accept.station.out="*"
3. accept.wb.in="*"
4. accept.wb.out="*"

C. Provide a printed copy of the license agreement as part of the submittal package.

2.07 OPERATOR INTERFACE

A. The web server shall reside on a high-speed network with the building controllers. Web pages generated by this server shall be compatible with the latest versions of Microsoft Internet Explorer or Edge, Google Chrome, Mozilla Firefox, and Apple Safari browsers. Any of these supported browsers connected to the server shall be able to access all system information. Mobile devices shall be recognized by the web server and shall supply the appropriate system content as needed. The Operator Interface (web server with client devices) 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. This includes the ability to configure and/or reconfigure the system from the client device (change programs, graphics, labels, etc.).

B. The system shall support an unlimited number of concurrent users.

C. Hardware:

1. Web server and/or workstation. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The web server may also be configured in client/server fashion to accommodate a "workstation" definition. In "workstation" configuration, the workstation will also perform as a server supplying additional clients as needed. The following hardware requirements apply:
   a. System storage shall have sufficient memory to accommodate:
      1) All required system software.
      2) A DDC database to accommodate, as a minimum, twice the size of the delivered system database.
      3) One year of archival 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.

D. The Web browser client shall support at a minimum, the following functions:

1. User log-on identification and password shall be required. If an unauthorized user attempts access, a blank web page shall be displayed. Security using Java authentication and encryption techniques to prevent unauthorized access shall be implemented.
2. Graphical screens developed for the graphical user interface shall be the same screens used for the Web browser client. Any animated graphical objects supported by the graphical user interface shall be supported by the Web browser interface.
3. HTML programming shall not be required to display system graphics or data on a Web page. HTML editing of the Web page shall be allowed if the user desires a specific look or format.

4. Storage of the graphical screens shall be in the web server, without requiring any graphics to be stored on the client machine. Systems that require graphics storage on each client are not acceptable.
5. Real-time values displayed on a Web page shall update automatically without requiring a manual “refresh” of the Web page.
6. Users shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:
   a. Modify common application objects, such as schedules, calendars, and set points in a graphical manner.
      1) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
      2) Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.
   b. Commands to start and stop binary objects shall be done by right clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
   c. View logs and charts.
   d. View and acknowledge alarms.
7. The system shall provide the capability to specify a user’s (as determined by the log-on user identification) home page. Provide the ability to limit a specific user to just their defined home page. From the home page, links to other views, or pages in the system shall be possible, if allowed by the system administrator.
8. Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or on Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

E. Hardware. Each computer Operator Workstation (OWS) or web server shall consist of the following:

1. Hardware Base. Hard disk shall have sufficient memory to store system software, one year of data for trended points, and a system database at least twice the size of the existing database at system acceptance. Configure computers and network connections if multiple computers are required to meet specified memory and performance. Web server shall have a minimum of:
   a. Dual Processor Intel Pentium 3.66 GHz processor
   b. 1 GB RAM
   c. 1 TB hard disk providing data at 200 MB/sec
   d. RAID 5 Configuration
   e. 128x CD-ROM drive
   f. Windows Server 2008 Operating System
   g. Serial, parallel, and network communication ports and cables required for proper system operation.
2. Provide one OWS in the Facilities Engineering Department, and one other location ad defined by the Owner. Base bids shall include these fully functional OWS stations.
3. OWS shall be complete with 17" SVGA color flat screen, sound card and speakers, and high-speed Internet access.
4. OWS shall be complete with all the software tools required for maintaining and expanding the system (vendor software to program the logic to go into the OWS).

5. Confirm workstation requirements with Owner prior to ordering.

F. Operator Functions. Operator interface shall allow each authorized operator to execute the following functions as a minimum:

1. Log In and Log Out. System shall require username and password to log in to operator interface.
2. Point-and-click Navigation. Operator interface shall be graphically based and shall allow operators to access graphics for equipment and geographic areas using point-and-click navigation.
3. View and Adjust Equipment Properties. Operators shall be able to view and monitor controlled equipment status and to adjust operating parameters such as setpoints, PID gains, on and off controls, and sensor calibration.
4. View and Adjust Operating Schedules. Operators shall be able to view scheduled operating hours of each schedulable piece of equipment on a weekly or monthly calendar-based graphical schedule display, to select and adjust each schedule and time period, and to simultaneously schedule related equipment. System shall clearly show exception schedules and holidays on the schedule display.
5. View and Respond to Alarms. Operators shall be able to view a list of currently active system alarms, to acknowledge each alarm, and to clear (delete) unneeded alarms.
6. View and Configure Trends. Operators shall be able to view a trend graph of each trended point and to edit graph configuration to display a specific time period or data range. Operator shall be able to create custom trend graphs to display on the same page data from multiple trended points.
7. View and Configure Reports. Operators shall be able to run preconfigured reports, to view report results, and to customize report configuration to show data of interest.
8. Manage Control System Hardware. Operators shall be able to view controller status, to restart (reboot) each controller, and to download new control software to each controller.
9. Manage Operator Access. Typically, only a few operators are authorized to manage operator access. Authorized operators shall be able to view a list of operators with system access and of functions they can perform while logged in. Operators shall be able to add operators, to delete operators, and to edit operator function authorization. Operator shall be able to authorize each operator function separately.

G. System Tools. 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 PCs with no limit on the number of copies that can be installed under the system license. Refer to subscription service notes above.

1. 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, historical trends and all security audit information. Stored

database, control logic, and parameters shall be automatically updated with each system configuration or controller firmware or software change.

2. Controller Memory Download. Operators shall be able to download memory from the system database to each controller.
3. System Configuration. Operators shall be able to configure the system.
4. Online Help. Context-sensitive online help for each tool shall assist operators in operating and editing the system.
5. Security. System shall require a username and password to view, edit, add, or delete data.
    a. Operator Access. Each username and password combination shall define accessible viewing, editing, adding, and deleting functions in each system application, editor, and object. Authorized operators shall be able to vary and deny each operator's accessible functions based on equipment or geographic location.
    b. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. Operators shall be able to adjust automatic log out delay.
    c. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.
6. System Diagnostics. System shall automatically monitor controller and I/O point operation. System can annunciate any controller failure.
7. 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 Sequences of Operation. Alarms shall be BACnet alarm objects and shall use BACnet alarm services.
    a. Alarm Messages. Alarm messages shall use an English language descriptor without acronyms or mnemonics to describe alarm source, location, and nature.
    b. Alarm Reactions. Operator shall be able to configure (by object) actions workstation or web server shall initiate on receipt of each alarm. As a minimum, workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.
    c. Alarm Maintenance. Operators shall be able to view system alarms and changes of state chronologically, to acknowledge and delete alarms, and to archive closed alarms to the workstation or web server hard disk from each workstation or web browser interface.
    d. Trend Configuration. 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. The contractor shall configure all physical control points and software control points to accumulate trend data. Analog values shall be configured utilizing time-based intervals and digital values shall be configured for COV. Provide at a minimum of 1344 samples per control point.

8. Object and Property Status and Control. Operator shall be able to view, and to edit the status of each system object and property by menu, on graphics, or through custom programs.
9. 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.
10. Standard Reports. Furnish the following standard system reports:
    a. 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.
    b. Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
    c. Logs. System shall log the following to a database or text file and shall retain data for an adjustable period:
        1) Alarm History.
        2) Trend Data. Operator shall be able to select trends to be logged.
        3) 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.
        4) All log data shall be available to the user in the following data formats: HTML, XML, Plain Text, Comma or tab separated values.
        5) Systems that do not provide log data in HTML and XML formats at a minimum shall not be acceptable.
11. 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.
12. 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. Minimum graphics resolution shall be 1920 x1080 for display of detailed system graphics.
    b. 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.
    c. Animation. Graphics shall be able to animate by displaying different image files for changed object status.
    d. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
    e. Format. Graphics shall be saved in an industry-standard format such a 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) or shall only

require widely available no-cost plug-ins (such as Active-X or Adobe Flash).

13. 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 to create and modify graphics that are saved in the same formats as are used for system graphics.
14. 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.
15. 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.
16. Custom Application Programming. Operator shall be able to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:
    a. Language. Language shall be graphically based. Graphically based language shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks.
    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.

2.08 CONTROLLER SOFTWARE

A. Building control and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

B. Scheduling. System shall provide the following schedule options as a minimum:

1. Weekly. 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. Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.
3. Holiday. Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

C. Demand Limiting.

1. System shall monitor building power consumption from building power meter pulse generator signals or from building feeder line watt transducer or current transformer.
2. The program shall predict probable power demand such that action can be taken to prevent exceeding the demand limit. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand. When demand drops below adjustable levels, system shall restore loads as specified.

3. Demand limiting prediction and control shall be provided for any individual meter or for the total of any combination of meters that are monitored by the BAS.
4. Demand reduction shall be accomplished by:
   a. Resetting air handling unit supply temperature set point up by 2°F.
   b. Resetting space temperature setpoints up by 2°F.
   c. De-energize equipment based upon priority that shall be predetermined by the operator
5. Frequency of calculations, parameters, time interval, and other variables shall be based on how the local power company computes the demand charges.
6. Operator shall be able to make the following changes:
   a. Changes in demand interval
   b. Changes in demand limit for meter(s)
   c. Addition and deletion of controlled loads
   d. Maximum and minimum shutoff time for equipment
   e. Shed and Restore priority
   f. Select Rotational or Sequential Shedding and Restoring
7. The following reports shall be available as an hourly, daily, and monthly basis:
   a. Date and Time of Peak Demand
   b. Daily Peak Demand
   c. Peak Demand
   d. Total Electric Consumption

D. Maintenance Management. System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as required by Owner.

E. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified on Drawings in Sequences of Operation.

F. 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.

G. 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.

H. Energy Calculations

1. System shall accumulate and convert instantaneous power (kW), natural or LP gas flow rates (CFH) or water flow rates (GPM) to energy usage data.
2. 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.
3. System shall calculate a fixed-window average. Window interval start shall be defined by utility meter digital input signal to synchronize system's and utility's fixed-window averages.

I. Anti-Short Cycling. Binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

J. On and Off Control with Differential. System shall provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and set point.

K. Runtime Totalization. System shall provide an algorithm that can totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. The operator shall also be able to reset totalization before and/or after run limit is reached.

2.09 CONTROLLERS

A. General. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), and Smart Actuators (SA) as required to achieve performance specified in paragraph 1.05 (System Performance).

B. Provide one or more Native BACnet application controllers for each primary system such as air handler, chiller and boiler. 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 via MS/TP or ArcNet 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 units. Controllers shall be fully programmable using graphical programming blocks. Programming tool shall be resident on the application controllers. Controllers shall come standard with a color operator interface that provides real-time access to monitored inputs, setpoints, modes, values, statuses and outputs.

C. BACnet

1. Building Controllers (BCs). Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ASHRAE/ANSI 135, BACnet Annex L, and shall be listed as a certified B-BC in BACnet Testing Laboratories (BTL) Product Listing. The Building Controllers shall be equal to a Tridium Niagara N4 JACE with 256 MB of RAM at a minimum.
2. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ASHRAE/ANSI 135-2001, 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 ASHRAE/ANSI 135-2001, BACnet Annex Land shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.

4. Smart Actuators (SAs). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ASH RAE/ANSI 135-2001, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.
5. BACnet Conformance:
   a. Application controllers shall as a minimum support MS/TP BACnet or ArcNet LAN types. They shall communicate directly via this BACnet LAN at 9.6, 19.2, 38.4, 76.8, and 156 Kbps, as Native BACnet devices.
   b. 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.

D. Communication

1. Application controllers shall include universal inputs with 16-bit resolution that accept 10K thermistors, 0–10VDC, 0–5 VDC, 4–20 mA and dry contact signals. Any input on a controller may be either analog or digital with a minimum of 3 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 shall be selectable as either 0–10VDC or 0–20mA. Software shall include scaling features for analog outputs. Application controller shall include 24VDC voltage supply for use as power supply to external sensors.
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 shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All 1/0 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.

E. 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 -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 32°F to 120°F.

F. Serviceability

1. Controllers shall have diagnostic LEDs for power, communication, and processor.
2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.

3. 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.

G. 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.
4. The system will restore to its last saved settings.

H. 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 Watt at 1 m (3 ft).

I. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

J. UPS. Each controller shall be provided with a 72-hour battery backup system.

2.10 I/O INTERFACE

A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.

B. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output contact with up to 24 V for any duration shall cause no controller damage.

C. Binary Inputs. Binary inputs shall monitor the on and off signal from a remote device. Binary inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.

D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall accumulate up to 10 pulses per second.

E. Analog Inputs. Analog inputs shall monitor low-voltage (0-10 Vdc), current (4-20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

F. Binary Outputs. Binary outputs shall send a pulsed low-voltage signal for pulse width modulation control or an on-or-off signal for on and off control. Building Controller binary

outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

G. Analog Outputs. Analog outputs shall send a modulating 0-10 Vdc or 4-20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.

H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

I. Pulse-Width Modulation. Control actuators designed for pulse-width modulation with a single binary output that cycles with variable on and off times as determined by the application software. Pulse-width modulation 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.

J. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

2.11 POWER SUPPLIES & 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 32°F and 120°F. EM/RF shall meet FCC Class Band VDE 0871 for Class B and MILSTD·81 OC for shock and vibration.
   b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering

1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:
   a. Dielectric strength of 1000 V minimum
   b. Response time of 10 nanoseconds or less
   c. Transverse mode noise attenuation of 65 dB or greater
   d. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

2.12 UNITARY APPLICATION CONTROLLERS AIR HANDLING UNITS, AC UNITS, FAN COIL UNITS)

A. General - Provide one (1) 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 via MS/TP or ArcNet LAN using BACnet protocol. No gateways shall be used. Controllers shall include input, output and self-contained logic program as needed for control of unit.

B. Application controllers shall include universal inputs that can accept 10K thermistors, 0–5 Vdc, 4–20 mA, 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 and analog outputs on board.

C. All program sequences shall be stored on-board the application controller. No batteries shall be needed to retain the logic program. All program sequences 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 via Ethernet connection. 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 system programming section.

D. Application controller shall include support for intelligent room sensor. Display on intelligent room sensor shall be programmable at controller. 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.

2.13 TOUCH SCREEN COMMUNICATING THERMOSTAT

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.

B. Touch screen Communicating Thermostat hardware shall:

1. Include a backlit touch screen for the user interface, buttons are not allowed.
2. Include Three (3) universal inputs with 12-bit resolution that can accept 3K and 10K Type II thermistors, 0-10 Vdc, 0–5 Vdc, 4-20mA, and dry contact signals. Inputs on controller may be either analog or digital.
3. Include built-in temperature sensor.

4. Include built-in humidity sensor.
5. Include Six (6) relay outputs on board.
6. Include Two (2) analog outputs with 12-bit resolution. Each auto-detecting for 0-10 Vdc or 4-20 mA control signals.
7. Meet the requirements of Listed Underwriters Laboratory for Open Energy Management Equipment (PAZX) under the UL Standard for Safety 916.
8. Meet the requirements for FCC Part 15, Class B.
9. Be powered by 24 Vac power.

2.14 AUXILIARY CONTROL DEVICES

A. Motorized Control Dampers

1. Type. AMCA-rated control dampers shall have linear flow characteristics and shall be 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 13-gauge galvanized steel channel or 1/8 in. extruded aluminum with reinforced corner bracing.
3. Blades. Damper blades shall not exceed 8 in. in width or 48 in. in length. Blades shall be suitable for medium velocity 2000 fpm performance. Blades shall be not less than 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 10 CFM/SF at 4 in. w.g. differential pressure when damper is held by torque of 50 in. x lbf.; when tested according to AMCA 500D. Blades shall be airfoil type suitable for wide-open face velocity of 1500 fpm.
6. Sections. Damper sections shall not exceed 48 in. - 60 in. Each section shall have at least one damper actuator.
7. 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. Electric Motors shall be sized to operate with sufficient reserve power to provide smooth modulating action. Spring return motors (for valves larger than 2½", and dampers larger than 25 sq. ft.) shall be sized for running and breakaway torque of 150 in. x lbf.
4. 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.

5. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
6. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 60 in.-lb torque capacity shall have a manual crank.

C. Control Valves

1. General. Factory fabricated, of type, body and trim materials in accordance with manufacturer's recommendations for design conditions and service shown. Pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated. All valves shall have override ability if actuator fails.
2. Type. Provide two- or three-way control valves for two-position or modulating service as shown.
3. Water Valves
   a. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
   b. Close-off (Differential) Pressure Rating. Valve actuator and trim shall provide the following minimum close-off pressure ratings.
      1) Two-way: 150% of total system (pump) head, but not less than 45 psi.
      2) Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.
   c. Ports. Valves providing modulating service shall have equal percentage ports.
   d. Valves ½" - 2" shall be pressure independent characterized type. The balancing valves and associated balancing shall not be required on devices where pressure independent control valves are installed. Balancing valves and balancing are required if self-contained pressure independent control valves are not installed.
      1) The absolute flow accuracy through the valve shall be +/- 5% due to system pressure fluctuations across the valve in the selected operating range.
      2) The control valves shall be available with floating or proportional actuators. The actuator shall be directly coupled to the valve at the factory. Multi-turn actuators are not acceptable.
      3) The valve shall have an equal percentage characteristic and shall accurately control the flow from 0-100% full rated flow.
      4) A minimum of 5 psi shall be required to operate the valve pressure independently.
      5) Valves shall not include replaceable cartridges.
      6) Valves shall be provided with pressure/temperature ports to allow flow verification.
      7) Alternate – Provide an automatic flow control valve, Basis-of-Design product Hays Fluid Controls; Mesurflo or a comparable

product by Flow Design Inc, Griswold Controls, Oventrop, or HCI; Hydronics Components Inc. The body shall be brass or ferrous metal. The flow control assembly shall be Mesurflo elastomeric diaphragm and polyphenylsulfone orifice plate, operating within 2- to 80-psig differential pressure operating ranges. The corrosion-resistant, tamper-proof, self-cleaning, and removable flow control assembly device shall be warranted for the life of the HVAC system in which it was originally installed, provided only water-based hydronic fluids are used at usual HVAC temperatures and installed according to the product installation and operation specifications. Combination assemblies shall include a bronze or brass-alloy ball valve. Size shall be the same as the pipe in which it is installed. Overall performance of the automatic flow control valve shall maintain a constant flow at a minimum of plus or minus 10 percent, of system pressure fluctuations. Minimum CWP Rating shall be 400 psig. Maximum operating temperature shall be 225ºF.

e. Valves 2½" and larger shall be cast iron (ANSI Class 125), with guided plug and EPDM O-ring or Teflon packing, unless otherwise indicated.

f. Sizing
   1) Two-position service: line size, unless otherwise shown.
   2) Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 5 psi.
   3) Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 5 psi.

g. Fail Position. Water valves shall fail normally open or closed as follows unless otherwise specified.
   1) Water zone valves: preferred normally open.
   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.

D. Binary Temperature Devices

1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 Vdc, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 55°F-85°F setpoint range, 2°F maximum differential, and vented ABS plastic cover.
2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetal actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 55°F-85°F setpoint range, 2°F maximum differential, and vented ABS plastic cover.
3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 20 ft long. Element shall sense temperature

in each 1 ft section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

E. Temperature Sensors

1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor. Sensor shall be vibration and corrosion resistant. Accuracy: +/- 0.5 F at calibration point. Minimum dead band of 5°F. Sensors shall be able to be calibrated at sensor or local controller terminal.
2. Duct Sensors. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 5 ft in length per 10 SF of duct cross-section. Install such that the sensing element is in the main air stream.
3. Immersion Sensors. Provide immersion sensors with a separable 316 stainless steel well. Sensor, well, wellhead, and Greenfield fitting shall be supplied as a complete assembly. Well construction and pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities. Mount thermo-well and sensor in a ½" NFT saddle or threadolet to allow easy access for repair or replacement of the sensor.
4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown. Space sensor shall have manufacturer standard locking cover (color coordinated with Architect). Wireless space sensors communication shall be installed and tested in accordance with manufacturer's instructions.
5. Differential Sensors. Provide matched sensors for differential temperature measurement.
6. Outside Air Sensors. Watertight inlet fitting. Install 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 shielded from direct sunlight.
7. Room Security Sensors. Stainless-steel cover plate with insulated back and security screws.

F. Humidity Sensors

1. Duct and room sensors shall have a sensing range of 5%-95% RH, accurate to +/- 2%. Humidity sensors for use in zones shall be provided with integrated temperature sensing in order to eliminate the need to have two sensors on the wall. Sensor shall be able to be calibrated at sensor or local controller terminal.
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°F-170°F.
4. Humidity sensors shall not drift more than 1% of full scale annually.
5. Room air humidity sensor shall have manufacturer standard locking cover (color coordinated with Architect), with concealed set-point adjustment and indication.
6. Output signal shall be either 0-10Vdc or 4-20mA.
7. Humidity transmitters shall be factory calibrated and require no field setting.

G. CO_2 Sensors

1. CO_2 sensors shall be space or duct mounted carbon dioxide sensors as required by the application. Space CO_2 sensors shall be mounted next to space temperature sensors. The sensor shall have a range of 0-2000 ppm with an accuracy of ±5%. The response time for the sensor shall be less than one minute. The sensor shall be capable of providing an analog signal proportional to the CO_2 level sensed. The signal shall be either 0-10 Vdc or 4-20mA.

H. Status Sensors

1. Differential Pressure Switches. Differential pressure switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 Vac minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.
2. Status Inputs for Electric Motors: Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.
3. Voltage Transmitter (100- to 600-Vac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.
4. Power Monitor: 3-phase type with disconnect/shorting switch assembly, UL listed voltage and split-core current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.
5. Current Sensing Relays: Provide current switches for indication of equipment status. Amperage ratings shall be adjustable with the desired setpoint to be in the top 50% of the current relay's operating range. Current sensing relays shall incorporate trip indication LED's and shall be sized for proper operation with the equipment served.
6. Electronic Valve/Damper Position Indicator: Visual scale indicating percent of travel and 2 to 10 Vdc feedback signal.

I. Air Flow Monitoring

1. Type: Project shall use thermal dispersion flow meter devices only (hermetically sealed "Bead-in-glass" thermistor probes only). Chip thermistors are not allowed. Velocity pressure averaging probes and arrays, differential pressure devices, and vortex shedding devices are not allowed for air flow measurement.
2. Sensor probes shall allow for "Plug-and-Play" installation to transmitter. Each sensor shall provide an independent air flow rate prior to averaging for multi-point sensing. Probes shall not induce a measurable pressure drop, or affect sound levels (by a singular or multiple presence in the air stream).
3. Manufacturer Basis of Design: Air Monitor Corp., Dietrich Standard, Ebtron, Tek-Air, Kele, Ruskin.
4. Quality Assurance: Factory calibrated to NIST-traceable airflow and temperature standards, UL 873 Airflow & Temperature Indicating Devices Listing.
5. Sensor Accuracy: +/-2% of reading (Airflow rate), +/-0.15°F (Temperature).
6. Warranty: Three years (3) from date of shipment.
7. Transmitter:

a. Transmitter shall be fully independent of the sensor probes and shall not require field matching to the sensor probes.
b. Transmitter shall have a high-speed microprocessor for "near-instantaneous" readings from the array of sensors.
c. Transducer Accuracy shall be 0.1% of Full Scale. The accuracy shall be evaluated at the maximum turndown.
d. Fused and protected switching power supply.
e. RS-485 output protocol (BACnet - MS/TP) with field selectable scales for integration into the BAS system.
f. Gold plated circuit board interconnects and pins for long life and stability.
g. LCD display for direct readout of airflow and temperature. Push button interface allows easy interface for configuration or diagnostics.
h. Adjustable airflow dampening filter to smooth output signal for monitoring.
i. Arithmetic or velocity weighted temperature output for true temperature measurement.
j. Analog test output signal (diagnostic tool for BAS contractor during startup).

8. Duct Airflow Measuring Station:
   a. Conformance: Device shall be built and designed to comply with, and provide results in accordance with, accepted practices as defined in the ASHRAE Handbook of Fundamentals (System Testing), and the Industrial Ventilation Manual, latest edition.
   b. Fabrication: Minimum 14-gauge galvanized steel welded casing, with 90-degree connecting flanges. Configuration and size suitable to duct into which it is mounted.
   c. Provide air directionalizer and parallel cell honeycomb suppressor providing a minimum 98% free area, eliminate turbulent and rotational flow from the air stream, and equalize the velocity profile prior to the measuring point. The parallel cell profile suppressor shall have a ¾" maximum cell across the entering air stream, and fastened to the casing to withstand up to 6000 FPM.
   d. Total Pressure (High) Measurement Side: Spaced and designed for self-averaging per the Industrial Ventilation Manual.
   e. Static Pressure (Low) Measurement Probes: As illustrated in the Industrial Ventilation Manual.
   f. Both total and static pressure manifold take-off points must be symmetrical.
9. Fan Inlet Airflow Measuring Station:
   a. Stations shall be provided with probes to continuously monitor the fan air volume and temperature. Stations shall be located at the inlet of each fan as recommended by manufacturer.
   b. Sensor(s) shall be on adjustable mounting brackets to facilitate selection and installation. Sensor mounting blocks and mounting feet constructed of 304 stainless steel.
10. Duct Static Pressure Traverse Probe: Provide as required to monitor duct static pressure. Manufacturer Basis of Design - Paragon Controls Inc. (PE-5000). The probe shall contain multiple static pressure sensors located along the exterior surface of the cylindrical probe.

11. Single Probe Measuring Sensor: Duct mounted with an adjustable sensor insertion length of up to eight inches. The sensor shall be a hot wire anemometer and utilize two temperature sensors and a heater element thermistor. The other sensor shall measure downstream air temperature. The temperature differential shall be directly related to air flow velocity. The transmitter shall produce a 0-10 Vdc or 4-20 mA signal, linear to air velocity.
12. Shielded Static Pressure Probe: Multiple sensing ports with an impulse suppression chamber and airflow shielding, suitable for indoor and outdoor locations. Provide a probe at each end of the building.

J. Alarm Panels

1. Unitized cabinet with suitable brackets for wall or floor mounting. Panels shall be fabricated of 0.06-inch thick, furniture-quality steel or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock with manufacturer's standard shop-painted finish. Provide a common key for all panels. Panels shall be purchased by the General Contractor. Controls contractor shall be responsible for wiring and integration from the BAS to the panel. The external panel’s controller shall be BACnet compatible.
2. Each panel shall include an indicating light for each alarm point, acknowledge switch, single horn, and test switch all mounted on a hinged cover.
   a. Alarm Condition: Indicating light flashes and horn sounds.
   b. Acknowledge Switch: Horn is silent and indicating light is steady.
   c. Second Alarm: Horn sounds and indicating light is steady.
   d. Alarm Condition Cleared: System is reset and indicating light is extinguished.
   e. Contacts in alarm panel allow remote monitoring.

K. Manual Override Stations (External)

1. Station shall provide an integral HAND/OFF/AUTO switch to override the controlled device relay.
2. Provide a status input to the BAS to indicate whenever the switch is not in the AUTO position.
3. Provide a Status LED to illuminate whenever the output is ON.
4. Provide an Override LED to illuminate whenever the HOA switch is in either the OFF or HAND position.
5. Contacts shall be rated for 1 amp (minimum) at 24 Vac.

L. Smoke Detectors. Ionization type air duct detectors shall be furnished as specified in Division 28 (Fire Alarm System) for installation under Division 26. All wiring shall be provided under Division 28. Coordinate interface with BAS and Fire Alarm System.

M. Flow Switches. Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service) to monitor equipment status and safety conditions. Switches shall be UL listed, SPDT snap-acting, and pilot duty rated (125 Vac minimum). Switches shall generate alarms at the BAS when an abnormal condition or failure occurs. Safety switches shall be provided with two sets of contacts and shall be interlocked to shut down the respective equipment.

1. Paddle switches shall have adjustable sensitivity and NEMA 250, Type 1 enclosure unless otherwise specified.
2. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 250, Type 1 enclosure unless otherwise specified.
3. Air Filter Status Switches shall be of the automatic reset type, equal to Cleveland Controls or Dwyer. Provide a complete installation kit, including air filters, fittings, static pressure tips, and tubing.

N. Freeze Protection Switch. Manual reset type with 20-foot capillary element able to respond to the coldest section of its length, serpentine across the entering air face of center cooling coil. Capillary range from 20-60°F. Line voltage with bellows-actuated switch. Snap acting SPDT throw switch shall be moisture-proof and dust-proof.

O. Relays

1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have a 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.

P. 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.

Q. 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/I SA S50.1 requirements and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation.

S. 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.

T. 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 ANSl/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.

U. Voltage Transformers

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

V. Pressure Transducers

1. Static pressure transducers shall be 100% solid state and shall include glass on silicon, ultra-stable capacitance sensors. Each static pressure transducer shall incorporate short circuit and reverse polarity protection. Transmitter output shall be either 0-10 Vdc or 4-20 mA. The desired setpoint is to be in the top 50% of the transmitter's operating range.
2. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 150 psi. Transducer shall have 4-20 mA output, suitable mounting provisions, and block and bleed valves.
3. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 150 psi. Over-range limit (differential pressure) and maximum static pressure shall be 300 psi. Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

W. Static-Pressure Transmitter

1. Transmitter shall have a 4-20 mA output, with a range of 0- to 0.25-inch wg for building, 0 to 5-inch wg for ducts.
2. Pressure transmitters shall be direct acting for gas, liquid, or steam service, with a range suitable for system. Transmitter shall have a 4-20 mA linear output.

X. Water Detectors

1. Detector equal to MX Series from Veris Industries.
2. Detector shall be able to operate at 12-24 Vac or dc. Contacts shall be gold-plated. Solid state output shall be 100 mA, NC (failsafe).

Y. Zone Water Detector

1. Detector shall be equal to Darwell Integrated Technology, Inc. model AT1-M zone water detection system through AT1-XXM woven water sensing cable or ribbon.
2. Detector shall be able to operate at 12-24 Vac or dc.
3. Water detection through sensing cable. Module shall be able to provide control for up to 100 feet of sensing cable.
4. Contacts shall change states and signal an alarm condition to the DDC if a leak is detected, an internal malfunction occurs, the sensing cable becomes disconnected from the zone module, or power is lost to the sensor.
5. System shall be self-contained.
6. Cable shall be supplied with hold-down clips or waterproof adhesive for secure mounting. Cable shall be provided with connectors for additional cable lengthening in series.
7. Install per manufacturer's recommendations.

Z. Power Meters

1. Metering system shall be Ohio Semitronics, Inc. A2000 Multifunction Power Meter with 4 analog outputs, 2 pulse outputs, and data logging, or approved equal.
   a. Metering system shall be suited for stand-alone metering in custom panels, switchboards, generators, switchgear, motor control centers and UPS systems.
   b. The metering device shall provide local indication of energy (kVA), and power (kW) data through alphanumeric LCD. Serial communication output shall be provided for relaying all information to the BAS.
   c. The metering device shall be factory programmed and ready for use upon delivery.
   d. Device shall meet or exceed IEC 60687 class 0.5% accuracy.
   e. Device shall operate in a temperature range of 20ºF to 150ºF, and a humidity range of 5% to 90% non-condensing.
   f. Memory shall be non-volatile and retain all program parameters and totalization values in the event of a power loss.
   g. Install power meter per manufacturer's recommendations.

AA. BTU Water Meters

1. Metering system shall be equal to Onicon Inc. System 10-BTU Meter. The flow metering devices shall either be an inline or insertion style electromagnetic flow meter. The BTU meter shall be furnished with supply and return temperature sensors.
   a. The flow meters shall be either an inline electromagnetic flow meter model F-3200 or insertion electromagnetic flow meter model F-3500.
   b. The metering device shall provide local indication of energy, flow, and temperature data through an alphanumeric LCD display. The BTU meter shall provide the following points both at the integral LCD and as outputs to the building control system: Energy Total, Energy Rate, Flow Rate, Supply Temperature, and Return Temperature. Output signals shall be either serial network (protocol conforming to BACnet MS/TP, BACnet/IP, LONWORKS, JCI-N2, MODBUS RTU RS485, MODBUS RTU TCP/IP, or Siemens-P1) and/or via individual analog and pulse outputs. Each BTU

meter shall be factory programmed for its specific application and shall be re-programmable using the front panel keypad (no special interface device or computer required).

c. Temperature sensors shall be loop-powered current-based (mA) sensors and shall be bath-calibrated and matched (NIST* traceable) for the specific temperature range for each application. The calculated differential temperature used in the energy calculation shall be accurate to within +0.15°F (including the error from individual temperature sensors, sensor matching, input offsets, and calculations).

d. Computing shall be nonlinearity within +/- 0.05%.

e. Metering device shall be factory programmed and ready for use upon delivery.

f. Memory shall be non-volatile and retain all program parameters and totalization values in the event of a power loss.

g. Install per manufacturer's recommendations.

2.16 ENCLOSURES

A. NEMA 2 rated enclosures for inside mounting, provide with weather shield for outside mounting.

B. All controllers, power supplies and relays shall be mounted in enclosures.

C. 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.

D. Enclosures shall have hinged, locking doors.

E. All direct digital controllers located indoors shall be installed in NEMA 1 enclosures. All direct digital controllers located outdoors shall be installed in NEMA 3R enclosures. Enclosures shall be of suitable size to accommodate all power supplies, relays and accessories required for the application. Each enclosure shall include a perforated subpanel for direct mounting of the enclosed devices. Include matched key locks for all enclosures provided.

2.17 AUTOMATIC SHUTDOWN OF RECIRCULATING AIR SYSTEMS

A. All fans supplying more than 2,000 cfm of air to any space shall be installed with a smoke detector in the return ductwork. Duct smoke detectors shall be installed in the return air path of air distribution systems utilizing a common supply and/or return air plenum with a combined design capacity greater than 2,000 CFM.

B. The smoke detector shall be wired to stop the fan upon detection of smoke and signal the building fire alarm control panel. The smoke detector shall be furnished by the Electrical Contractor, mounted in the duct by the HVAC Contractor, and wired by the Electrical Contractor. The smoke detector/shutdown relay shall be installed within 3 feet of the safety shut down controller.

2.18 DAMPER ACTUATORS FOR LIFE SAFETY SYSTEMS

A. This includes actuators controlling dampers for life safety systems, but not limited to generator ventilation and cooling, elevator hoistway relief, etc.

B. Actuators shall be powered closed and spring operated to fail open upon loss of power.

C. Actuators for UL listed smoke dampers and combination fire/smoke dampers are to be furnished by the damper manufacturer (Re: Section 23 31 00 Ductwork & Accessories for additional information).

PART 3 - EXECUTION

3.01 EXAMINATION

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

B. Thoroughly examine project plans for control device and equipment location. Report discrepancies, conflicts, or omissions to Architect or Engineer before starting rough-in work.

C. Notify the Owner’s representative in writing of conditions detrimental to the proper and timely completion of the work.

D. Inspect site to verify that duct-, pipe-, and equipment-mounted devices can be installed as shown before proceeding with installation. Report discrepancies, conflicts, or omissions to the Engineer before starting rough-in work.

E. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to the Architect. The Controls Contractor shall perform, at his expense, necessary changes in specified work caused by failure or neglect to report discrepancies.

3.02 OPERATION

A. BACnet Object List:

1. The following points as defined for each piece of equipment are designated as follows:
   a. Binary Out (BO) – Defined as any two-state output (start/stop) (enable/disable), etc.
   b. Binary In (BI) - Defined as any two-state input (alarm, status), etc.
   c. Analog In (AI) - Defined as any variable input (temperature) (position), etc.
   d. Analog Out (AO) - Defined as any electrical variable output. 0–20mA, 4–20mA and 0–10 Vdc are the only acceptable analog outputs. The driver for analog outputs must come from both hardware and software resident

in the controllers. Transducers will not be acceptable under any circumstance.

2. Each and every point will be checked out by the Contractor and the Owner's Representative will inspect each point with the bidder prior to acceptance. Provide complete written documented inspections, test and checkout report. Calibrate all equipment.

3.03 INSTALLATION

A. Install software in control units to be accessible by the web server. Implement all features of programs to specified requirements and as appropriate to sequence of operation.

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 any point schedules.

C. Provide a complete and operational temperature control and building automation system based on the following points and sequence of operation. The system shall be complete as to sequences and standard control practices. The determined point list, if provided, is the minimum amount of points that are to be provided. If additional points are required to meet the sequence of operation, they shall be provided.

D. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible. Route cable in a professional, neat and orderly manner. Cable bends shall not exceed the manufacturers' suggested bend radius. Enclosures and hardware or wiring shall not block or limit accessibility to service compartments of any other equipment. All wiring shall be in accordance with Division 26 requirements.

E. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults. All instruments, switches, transmitters, etc., shall be suitably wired and mounted to protect them from vibration, moisture and high or low temperatures.

F. Termination practices

1. Strip back only as much cable jacket as required to terminate.
2. Preserve wire twists as closely as possible to point of termination (0.5" maximum) to keep signal impairment to a minimum.
3. Avoid twisting cable during installation.
4. No terminations or splices shall be installed in or above ceilings. Cable shall be continuous from one device termination to the next.
5. Electrical interlocks – All electrical interlocks shall be provided as specified. All electrical interlocks shall be made by means of motor starters or shall be accomplished by separate relays. No motor power lead shall be utilized in an interlock circuit.

G. Equipment, installation, and wiring shall comply with industry specifications and standards and local codes for compatibility, performance, and reliability. All cabling shall be placed with regard to the environment, EMI/RFI (interference) and its effect on communication signal transmission.

H. Each cable run shall include a three-foot service loop with wire tie located in the ceiling above the control unit panel. This is to allow for future re-termination or repair.

I. Do not route any controls cable within two feet of any light fixture, HVAC unit service access area, electric panel, or any device containing a motor or transformer.

J. 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.

K. Cable installation and attachments

1. The support system shall provide a protective pathway to eliminate stress that could damage the cabling. The cable shall not be crushed, deformed, skinned, crimped, twisted, or formed into tight radius bends that could compromise the integrity of the cabling. Controls cables shall not be run loose on ceiling grid or ceiling tiles. Support shall be provided by mounting appropriate fasteners which may be loaded with multiple cables. Provided that the weight load is carried by the support rod or wire, the support assembly may attach to the ceiling grid for lateral stabilization. The required support wires for the ceiling grid or light fixtures shall not be utilized. Any fastener attached to the ceiling grid shall not interfere with inserting or removing ceiling tiles. All cabling and supports must be positioned at least 12 inches above the ceiling grid.
2. Controls cables shall be run in bundles above accessible ceilings and supported from building structure. Cabling shall be loosely bundled with wire wraps randomly spaced at 30 to 48 inches on center, wire wraps shall not be tight enough to deform cabling and shall not be used to support the cabling.
3. Do not mix different signal strength cables on the same J-Hook (i.e. fire alarm, 25-volt speaker cable). Multiple J-Hooks can be on the same attachment point up to the rated weight of the attachment device.
4. Controls cables shall be run in conduit stubs, where stubs are provided, from wall mounted devices to above accessible ceilings. Conduit shall be required only within walls and concealed spaces to provide access. Provide a plastic snap bushing or sleeve on the end of each conduit stub.
5. Conduit, duct or track shall be used for controls cable in exposed areas.
6. All conduit, ducts, track and raceways shall be supported from the structure at industry standard intervals for the size specified, utilizing proper anchoring devices and techniques for each type of cable used.
7. All penetrations through fire rated walls or floors shall feature a short length of metal conduit. The hole shall be neatly cut, not oversize or irregular. Seal the interior of the conduit sleeve around the cables and around the outside of the sleeve on each side of the penetration with fire-stop caulk or putty.

L. Verify location of thermostats, humidistats, and other exposed control sensors with the Drawings, especially Interior Design Drawings, and room details before installation. Install devices per ADA requirements.

1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.

M. Install tamper-proof, lockable guards on space sensors in Entrances, Public Areas, and where indicated on the Drawings.

N. Install water differential pressure status switches with manifolds and shut off valves for isolation as required by the manufacturer for maintenance.

O. Installation of Sensors

1. Install sensors according to manufacturer's recommendations.
2. Mount sensors rigidly and adequately for the operating environment.
3. Install room temperature sensors on concealed junction boxes properly supported by wall framing. Mounting height shall be as noted on the drawings.
4. Duct temperature sensors shall mount in an electrical box (through a hole in the duct) and positioned to be easily accessible for repair or replacement. Sensor shall be insertion type with lock nut and mounting plate as a complete assembly. Utilize an averaging sensor for ductwork greater than 48 inches in any dimension, or where air temperature stratification can exist, such as a mixed air plenum. Mount using factory approved element holders.
5. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.
6. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.
7. Install low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 1 ft of sensing element for each 1 ft^2 of coil area. Provide additional switches as necessary to provide full protection of the air stream for larger duct areas where the sensing element may not provide full coverage. Install low-limit temperature switch on the discharge side of the first water coil or steam coil in the airstream.
8. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.
9. Install outdoor air temperature sensors on north wall at the designated location and with a sun shield.
10. Differential Air Static Pressure
    a. Supply and Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
    b. Building Static Pressure. Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.
    c. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.
    d. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.

e. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

11. Smoke detectors, freeze stats, 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.

P. Flow Switch Installation

1. Use correct paddle for pipe diameter.
2. Adjust flow switch according to manufacturer's instructions.

Q. Air Flow Measuring Stations - the air flow passage of the station shall be the same size as the inside duct dimensions for insulated ductwork.

R. Actuators

1. General. Mount actuators and adapters according to manufacturer's recommendations.
2. Electric and Electronic Damper Actuators: Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation. Link actuators according to manufacturer's recommendations.
   a. For low-leakage dampers with seals, mount actuator with a minimum 5-degree travel available for damper seal tightening.
   b. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5 degrees open position, manually close the damper, then tighten linkage.
   c. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
   d. Provide necessary mounting hardware and linkages for actuator installation.
   e. Damper actuators mounted outdoors shall have outdoor rated enclosures.

S. Install automatic dampers according to Division 23 Section 23 31 00 “Ductwork and Accessories”.

T. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.

U. Install labels and nameplates to identify control components according to Division 23 Section “HVAC General”.

V. Install hydronic instrument wells, valves, and other accessories according to Division 23 Sections 23 21 13 “Piping and Accessories”, 23 05 23 “Valves for HVAC Piping” and 23 21 16 “Hydronic Piping Specialties”.

W. Install refrigerant instrument wells, valves, and other accessories according to Division 23 Section 23 23 00 “Refrigerant Piping”.

X. Install duct mounted manual volume control dampers according to Division 23 Section 23 31 00 “Ductwork and Accessories”.

Y. Install electronic and fiber-optic cables according to Division 27 Section “Communications Horizontal Cabling”.

3.04 IDENTIFICATION OF HARDWARE AND WIRING

A. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 2 inches of termination. All cables shall have a label on both ends utilizing a self-laminating, flexible vinyl film and non-smear nylon marking pens.

B. Permanently label or code each point of field terminal strips to show instrument or item served.

C. Label control panels with minimum ½" letters on laminated plastic nameplates.

D. Label each control component with a permanent label. Label plug-in components such that label remains stationary during component replacement.

E. Label valves with nameplates.

F. Manufacturer's nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

G. Label identifiers shall match record documents.

3.05 COORDINATION

A. Site

1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If installation without coordination causes interference with work of other trades, the Contractor shall correct conditions 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. Test and Balance

1. Provide the Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing. Train the Test and Balance Contractor to use control system interface tools. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
2. Provide a qualified technician to assist with testing and balancing the first 20 terminal units.

3. The Test and Balance Contractor shall return tools undamaged and in working condition at the completion of testing and balancing.

C. Life Safety

1. Duct smoke detectors required for air handler shutdown are provided and wired under Division 26.
2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23 and wired by Division 26.
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 26.

D. Coordination with Other Controls. Integrate with and coordinate controls and control devices furnished or installed by others as follows:

1. Communication media and equipment shall be provided as specified in Division 27.
2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described, regardless of where within the contract documents those products are described.
3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. The Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

3.06 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. Commissioning and start-up of the BAS system shall be performed by a factory-authorized service representative of the BAS Contractor or Manufacturer. Electrical subcontractors shall not perform this work.

C. Continually monitor field installation for code compliance and workmanship quality.

D. Control System Checkout and Testing - Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
2. Test and adjust controls and safeties.
3. Test each point through its full operating range to verify that safety and operating control set points are as required.

4. Startup Testing: Complete startup testing to verify operational control system before notifying Owner of system demonstration. Provide Owner with schedule for startup testing. Owner may have representative present during any or all startup testing.
   a. Calibrate and prepare for service each instrument, control, and accessory equipment.
   b. Verify that control wiring is properly connected and free of shorts and ground faults. Verify that terminations are tight.
   c. Enable control systems and verify each input device's calibration. Calibrate each device according to manufacturer's recommendations.
   d. Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.
   e. Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.
   f. Test wireless sensors in accordance with manufacturer’s instructions and fully document testing in startup log.
   g. Prepare a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated.
   h. Verify that system operates according to the sequences of operation. Simulate and observe each operational mode by overriding and varying inputs and schedules. Tune PID loops and each control routine that requires tuning.
   i. Alarms and Interlocks.
      1) Check each alarm with an appropriate signal at a value that will trip the alarm.
      2) Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.
      3) Test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

E. DDC Verification

1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
2. Check instruments for proper location and accessibility.
3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
4. Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.
5. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
6. Check temperature instruments and material and length of sensing elements.
7. Check control valves. Verify that they are in correct direction.

8. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.
9. Check DDC system as follows:
    a. Verify that DDC controller power supply is from emergency power supply, if applicable.
    b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
    c. Verify that spare I/O capacity has been provided.
    d. Verify that DDC controllers are protected from power supply surges.
    e. Verify that systems utilizing wireless communications fully comply with Paragraph 1.05.A – System Performance.

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

G. Relocate or reconfigure wireless communications devices as required to fully comply with Paragraph 1.05.A – System Performance. If additional communications devices are required (routers, switches, repeaters, etc.) these shall be provided, installed, and commissioned by the Controls Contractor at no additional cost.

H. Controls Contractor shall protect against and be liable for damage to work and to material caused by Contractor's work or employees.

I. Controls Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

    1. The General Contractor shall be responsible for wall sensors and control wiring/communication cabling damaged during construction.

J. The control system in its entirety shall be reviewed and tested by the Commissioning Agent (Cx). Specifically, the Mechanical and Controls Contractor shall create a testing matrix from the sequence of operation for each air handling system for the Cx to utilize and check off each mode after visually verifying each operation. The Cx shall submit the testing matrix to the Design Professional one (1) week prior to final inspection with all items checked and the Cx's signature of approval and date. The testing matrix shall be submitted to the Mechanical Engineer at 60% project completion for approval. Typical HVAC AHU Fire/Smoke Damper Control Matrix should include AHU fan status, supply damper status and return damper status for supply air detector activation and return air detector activation. Each status shall be verified and checked by the Cx. Typical HVAC Smoke Evacuation Mode Testing for AHU should include (if applicable); supply fan status, return fan status, relief damper status, return damper status, outside air fan status, outside air damper status, air handling units adjacent to zone status, air handling unit supply air fire/smoke damper status, return air fire/smoke damper status, interlocked exhaust fan status for area smoke detector activation, supply duct smoke detector activation, return duct smoke detector activation, outside air duct smoke detector activation and outside air/area smoke detector activation. Coordinate requirements with control drawings. Each status shall be verified and checked by the Cx.

3.07 PROGRAMMING

A. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation.

B. Software Programming. Programming shall provide actions for each possible situation.

1. Application Programming. Provide application programming that adheres to sequences of operation as indicated on Drawings.
2. System Programming. Provide system programming necessary for system operation.

C. Operator Interface

1. Standard Graphics. Show on each equipment graphic input and output points and relevant calculated points. Point information on graphics shall dynamically update.
2. Install, initialize, start-up, and troubleshoot operator interface software and functions (including operating system software, operator interface database, and third-party software installation and integration required for successful operator interface operation).

3.08 ADJUSTING

A. Calibrating and Adjusting

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

7. Temperature:
   a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
   b. Calibrate temperature switches to make or break contacts.
8. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
9. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
10. Provide diagnostic and test instruments for calibration and adjustment of system.
11. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures for review and approval before initiating startup procedures.

B. Adjust initial temperature and humidity set points.

C. Provide certificate stating that control system has been tested and adjusted for proper operation.

D. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to three visits to the Project during other than normal occupancy hours for this purpose.

3.09 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls.

B. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of any input and output points requested by the Engineer and/or the Cx. Provide and operate test equipment required to prove proper system operation. Demonstrations shall be performed in the presence of the Engineer, Cx and owner simultaneously.

C. Demonstrate compliance with sequences of operation through each operational mode.

D. Demonstrate complete operation of operator interface.

E. Demonstrate: DDC Loop Response, Demand Limiting, Building Fire Alarm System Interface, and Trend Logs for each system.

F. Tests that fail to demonstrate proper system operation shall be repeated after Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

G. Acceptance

1. After tests described in this specification are performed to the satisfaction of the Engineer, Cx and Owner, the Engineer will accept the control system as meeting completion requirements. Engineer may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control. Engineer will provide written statement of each exempted test. Exempted tests shall be performed as part of warranty.
2. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required in paragraph 1.08 (Submittals).

3.10 CLEANING

A. Each day clean up debris resulting from work. Remove packaging material as soon as its contents have been removed. Collect waste and place in designated location.

B. On completion of work in each area, clean-up work debris and equipment. Keep areas free from dust, dirt, and debris.

C. On completion of work, check equipment furnished under this section for paint damage. Repair damaged factory-finished paint to match adjacent areas. Replace deformed cabinets and enclosures with new material and repaint to match adjacent areas.

3.11 SEALING PENETRATIONS

A. All penetrations in walls, ceilings, and partitions required by controls work shall be sealed with an appropriate pliable sealant or fire caulking to make the penetration airtight and maintain the integrity of the fire rating. Penetrating items shall include, but not be limited to, conduit, cables, control wiring (especially for thermostats and sensors), hangers, mounting hardware, etc.

3.11 OPERATING SEQUENCE

A. All units and systems shall be controlled as described on the Drawings and as recommended by equipment manufacturers.

B. Coordinate with Owner in operating equipment to maximize comfort and economy.

C. Refer to the drawings for sequence of operation.

3.12 ADDITIONAL INSTRUCTIONS

A. Provide status and alarm points on the following equipment (if applicable) furnished and installed under other sections. Include furnishing and installing sensors, cabling and incorporating into graphic and alarm annunciation.

B. Make-up water for cooling towers, chilled water, hot water, tempered water systems to alarm and close valves if excessive flow is detected.

C. Domestic Water - Incoming meter, meter at cooling tower, domestic water pump status, surge tank level

D. Domestic Hot Water - Leaving water temperature, pump status

E. Fire Alarm - Alarm monitoring (full Fire Alarm integration), smoke dampers (damper position).

F. Electrical - Pre-trip alarms

G. Incoming Power - demand kilowatts, totalized kilowatts-hrs, loss of service, loss of phase

H. Generator - Status of generator

I. Elevator Pits - High water alarm

J. UPS System - Normal power, over/under voltage, battery power.

K. Lighting - Relays and contacts shown on electrical drawings, lighting blinking capability, override capability. Provide lighting contactors as scheduled on the electrical lighting drawings.

END OF SECTION

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SECTION 23 09 10 – CONTROL SEQUENCE OF OPERATIONS

1. Air Cooled Chiller (typical of 2)

Chiller - Run Conditions:
The chiller shall be enabled to run whenever:

- A definable number of chilled water coils need cooling

To prevent short cycling, the chiller shall run for and be off for minimum adjustable times (both user definable), unless shutdown on safeties or outside air conditions.

The chiller shall run subject to its own internal safeties and controls.

Emergency Shutdown:
The chiller shall shut down and an alarm generated upon receiving an emergency shutdown signal status.

Chilled Water Isolation Valve:
The valve shall open anytime the chiller is called to run. The valve shall also open whenever the chilled water pump runs for freeze protection.

The valve shall open prior to the chiller being enabled and shall close only after the chiller is disabled. The valve shall therefore have:

- A user adjustable delay on start.
- AND a user adjustable delay on stop.

The delay times shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.

Alarms shall be provided as follows:

- Failure: Valve commanded open but the status indicates closed.

- Open in Hand: Valve commanded closed but the status indicates open.
- Runtime Exceeded: Valve status runtime exceeds a user-definable limit.

Chilled Water Pump Lead/Standby Operation:
The two chilled water pumps shall run anytime the chillers is called to run. The chilled water pump shall also run for freeze protection whenever the outside air temperature is less than a user definable setpoint (adj.).

The lead pump shall start prior to the chiller being enabled and shall stop only after the chiller is disabled. The pump(s) shall therefore have:

- A user adjustable delay on start.
- AND a user adjustable delay on stop.

The delay times shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.

The two pumps shall operate in a lead/standby fashion.

- The lead pump shall run first.
- On failure of the lead pump, the standby pump shall run and the lead pump shall turn off.

The designated lead pump shall rotate upon one of the following conditions (user selectable):

- manually through a software switch
- if pump runtime (adj.) is exceeded
- daily
- weekly
- monthly

Alarms shall be provided as follows:

- Chilled Water Pump 1

- Failure: Commanded on, but the status is off.
- Running in Hand: Commanded off, but the status is on.
- Runtime Exceeded: Status runtime exceeds a user definable limit.
- VFD Fault.

- Chilled Water Pump 2
  - Failure: Commanded on, but the status is off.
  - Running in Hand: Commanded off, but the status is on.
  - Runtime Exceeded: Status runtime exceeds a user definable limit.
  - VFD Fault.

Chilled Water Differential Pressure Control:
The controller shall measure chilled water differential pressure and modulate the lead chilled water pump VFD to maintain its chilled water differential pressure setpoint. The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The controller shall modulate chilled water pump speed to maintain a chilled water differential pressure of 12lbf/in2 (adj.). The VFD minimum speed shall not drop below 20% (adj.).

Alarms shall be provided as follows:

- High Chilled Water Differential Pressure: If the chilled water differential pressure is 25% (adj.) greater than setpoint.
- Low Chilled Water Differential Pressure: If the chilled water differential pressure is 25% (adj.) less than setpoint.

Chilled Water Bypass Valve - Minimum Flow Control:
The controller shall measure chilled water flow through the chiller and, as the chilled water flow drops below setpoint, the controller shall modulate the chilled water bypass valve open to maintain the minimum chilled water flow setpoint.

Alarms shall be provided as follows:

- Low Chilled Water Flow: If the chilled water flow is 25% (adj.) less than setpoint.

Chiller:
The chiller shall be enabled a user adjustable time after pump statuses are proven on. The chiller shall therefore have a user adjustable delay on start.

The delay time shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.

The chiller shall run subject to its own internal safeties and controls.

Alarms shall be provided as follows:

- Chiller Failure: Commanded on, but the status is off.
- Chiller Running in Hand: Commanded off, but the status is on.
- Chiller Runtime Exceeded: Status runtime exceeds a user definable limit.

Chilled Water Supply Temperature Setpoint:
The chilled water supply temperature setpoint shall reset based on outside air temperature.

As outside air temperature drops from 75°F (adj.) to 50°F (adj.) the chilled water supply temperature setpoint shall reset upwards by adding from 0°F (adj.) to 10°F (adj.) to the current setpoint.

Chilled Water Temperature Monitoring:
The following temperatures shall be monitored:

- Chilled water supply.
- Chilled water return.

Alarms shall be provided as follows:

- High Chilled Water Supply Temp: If the chilled water supply temperature is greater than 55°F (adj.).

¶ Low Chilled Water Supply Temp: If the chilled water supply temperature is less than 38°F (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Chilled Water Differential Pressure	x								x		x
Chilled Water Flow	x								x		x
Chilled Water Return Temp	x								x		x
Chilled Water Supply Temp	x								x		x
Chilled Water Bypass Valve		x							x		x
Chilled Water Pump 1 VFD Speed		x							x		x
Chilled Water Pump 2 VFD Speed		x							x		x
Chilled Water Supply Temp Setpoint Reset		x							x		x
Chilled Water Isolation Valve Status			x						x		x
Chilled Water Pump 1 Status			x						x		x
Chilled Water Pump 1 VFD Fault			x							x	x
Chilled Water Pump 2 Status			x						x		x
Chilled Water Pump 2 VFD Fault			x							x	x
Chiller Status			x						x		x
Emergency Shutdown			x						x	x	x
Chilled Water Isolation Valve				x							x
Chilled Water Pump 1 Start/Stop				x					x		x
Chilled Water Pump 2 Start/Stop				x					x		x
Chiller Enable				x							x
Chilled Water Differential Pressure Set-point					x				x		x
Chilled Water Flow Setpoint					x				x		x
Outside Air Temp					x						x
Chilled Water Isolation Valve Failure										x	
Chilled Water Isolation Valve in Hand										x	
Chilled Water Isolation Valve Runtime Exceeded										x	
Chilled Water Pump 1 Failure										x	
Chilled Water Pump 1 Running in Hand										x	
Chilled Water Pump 1 Runtime Ex-ceeded										x	
Chilled Water Pump 2 Failure										x	
Chilled Water Pump 2 Running in Hand										x	
Chilled Water Pump 2 Runtime Ex-ceeded										x	
Chiller Failure										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Chiller Running in Hand										x	
Chiller Runtime Exceeded										x	
High Chilled Water Differential Pressure										x	
High Chilled Water Supply Temp										x	
Low Chilled Water Differential Pressure										x	
Low Chilled Water Flow										x	
Low Chilled Water Supply Temp										x	
Totals	**4**	**4**	**7**	**4**	**3**	**0**	**0**	**0**	**17**	**20**	**22**

Total Hardware (19) **Total Software (40)**

2. Single Zone AHU (typical)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain
  - A 75°F (adj.) cooling setpoint
  - A 70°F (adj.) heating setpoint.

- Unoccupied Mode (night setback): The unit shall maintain
  - A 85°F (adj.) cooling setpoint.
  - A 55°F (adj.) heating setpoint.

Alarms shall be provided as follows:

- High Zone Temp: If the zone temperature is greater than the cooling setpoint by a user definable amount (adj.).
- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Demand Limiting - Zone Setpoint Optimization:
To lower power consumption, the zone setpoints shall automatically relax when the facility power consumption exceeds definable thresholds. The amount of relaxation shall be individually configurable for each zone. The zone setpoints shall automatically return to their previous settings when the facility power consumption drops below the thresholds.

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Zone Optimal Start:
The unit shall use an optimal start algorithm for morning start-up. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.

Zone Unoccupied Override:
A timed local override control shall allow an occupant to override the schedule and place the unit into an occupied mode for an adjustable period of time. At the expiration of this time, control of the unit shall automatically return to the schedule.

Emergency Shutdown:
The unit shall shut down and generate an alarm upon receiving an emergency shutdown signal.

Supply Air Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status.

Supply Fan:
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 user definable (adj.) minimum runtime.

Alarms shall be provided as follows:

- Supply Fan Failure: Commanded on, but the status is off.
- Supply Fan in Hand: Commanded off, but the status is on.
- Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

Cooling Coil Valve:
The controller shall measure the zone temperature and modulate the cooling coil valve to maintain its cooling setpoint.

The cooling shall be enabled whenever:

- The economizer (if present) is disabled or fully open.
- AND the zone temperature is above cooling setpoint.
- AND the supply fan status is on.
- AND the heating is not active.

Electric Heating Stages:
The controller shall measure the zone temperature and modulate the heating to maintain its heating setpoint.

The heating shall be enabled whenever:

- The zone temperature is below heating setpoint.
- AND the supply fan status is on.
- AND the cooling is not active.

Final Filter Differential Pressure Monitor:
The controller shall monitor the differential pressure across the final filter.

Alarms shall be provided as follows:

- Final Filter Change Required: Final filter differential pressure exceeds a user definable limit (adj.).

Mixed Air Temperature:
The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).

Alarms shall be provided as follows:

- High Mixed Air Temp: If the mixed air temperature is greater than 90°F (adj.).
- Low Mixed Air Temp: If the mixed air temperature is less than 45°F (adj.).

Return Air Temperature:
The controller shall monitor the return air temperature and use as required for economizer control (if present).

Alarms shall be provided as follows:

- High Return Air Temp: If the return air temperature is greater than 90°F (adj.).

- Low Return Air Temp: If the return air temperature is less than 45°F (adj.).

Supply Air Temperature:
The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 120°F (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 45°F (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Final Filter Differential Pressure	x								x		
Mixed Air Temp	x								x		x
Return Air Temp	x								x		x
Supply Air Temp	x								x		x
Zone Setpoint Adjust	x										x
Zone Temp	x								x		x
Cooling Valve		x							x		x
Freezestat			x						x	x	x
Return Air Smoke Detector			x						x	x	x
Supply Fan Status			x						x		x
Zone Override			x						x		x
Heating Stage 1				x					x		x
Heating Stage 2				x					x		x
Supply Fan Start/Stop				x					x		x
Cooling Setpoint					x				x		x
Heating Setpoint					x				x		x
Emergency Shutdown						x				x	x
Schedule								x			
Final Filter Change Required										x	x
High Mixed Air Temp										x	
High Return Air Temp										x	
High Supply Air Temp										x	
High Zone Temp										x	
Low Mixed Air Temp										x	
Low Return Air Temp										x	
Low Supply Air Temp										x	
Low Zone Temp										x	

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
Totals	**6**	**1**	**4**	**3**	**2**	**1**	**0**	**1**	**15**	**15**	**17**

Total Hardware (14) **Total Software (34)**

3. Exhaust Fan - On/Off (typical)

Run Conditions - Scheduled:
The fan shall run according to a user definable schedule.

Fan:
The fan shall have a user definable (adj.) minimum runtime.

Exhaust Air Damper:
The exhaust air damper shall open anytime the unit runs and shall close anytime the unit stops. The exhaust air damper shall close 30 sec (adj.) after the fan stops.

Alarms shall be provided as follows:

- Damper Failure: Commanded open, but the status is closed.
- Damper in Hand: Commanded closed, but the status is open.

Damper Status:
The fan shall be enabled after the damper status has proven.

Alarms shall be provided as follows:

- Damper Failure: Commanded open, but the status is closed.
- Damper in Hand: Commanded closed, but the status is open.

Fan Status:
The controller shall monitor the fan status.

Alarms shall be provided as follows:

- Fan Failure: Commanded on, but the status is off.
- Fan in Hand: Commanded off, but the status is on.
- Fan Runtime Exceeded: Fan status runtime exceeds a user definable limit (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Exhaust Air Damper Status			x						x		x
Fan Status			x						x		x
Exhaust Air Damper				x					x		x
Fan Start/Stop				x					x		x
Schedule								x			
Exhaust Air Damper Failure										x	
Exhaust Air Damper in Hand										x	
Fan Failure										x	
Fan in Hand										x	
Fan Runtime Exceeded										x	
Totals	**0**	**0**	**2**	**2**	**0**	**0**	**0**	**1**	**4**	**5**	**4**

Total Hardware (4) **Total Software (10)**

4. Unit Heater (typical)

Run Conditions - Scheduled:
The unit shall run according to a user definable time schedule in the following modes:

- Occupied Mode: The unit shall maintain a heating setpoint of 70°F (adj.).
- Unoccupied Mode (night setback): The unit shall maintain a heating setpoint of 65°F (adj.).

Alarms shall be provided as follows:

- Low Zone Temp: If the zone temperature is less than the heating setpoint by a user definable amount (adj.).

Zone Setpoint Adjust:
The occupant shall be able to adjust the zone temperature heating and cooling setpoints at the zone sensor.

Fan:
The fan shall run anytime the zone temperature drops below heating setpoint, unless shutdown on safeties.

Electric Heating Stage:
The controller shall measure the zone temperature and stage the heating to maintain its heating setpoint. To prevent short cycling, the stage shall have a user definable (adj.) minimum runtime.

The heating shall be enabled whenever:

- The zone temperature is below heating setpoint.
- AND the fan is on.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Zone Setpoint Adjust	x										x
Zone Temp	x								x		x
Fan Start/Stop				x					x		x
Heating Stage 1				x					x		x
Heating Setpoint					x				x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Schedule								x			
Low Zone Temp										x	
Totals	**2**	**0**	**0**	**2**	**1**	**0**	**0**	**1**	**4**	**1**	**5**

Total Hardware (4) **Total Software (7)**

Total Hardware (8) **Total Software (17)**

5. Makeup Air Unit - Supply Air Temp - DOAS (typical of 4)

Run Conditions - Scheduled:
The unit shall run based upon an operator adjustable schedule.

Emergency Shutdown:
The unit shall shut down and generate an alarm upon receiving an emergency shutdown signal.

Freeze Protection:
The unit shall shut down and generate an alarm upon receiving a freezestat status.

Smoke Detection:
The unit shall shut down and generate an alarm upon receiving a smoke detector status.

Outside Air Damper:
The outside air damper shall open anytime the unit runs and shall close anytime the unit stops. The supply fan shall start only after the damper status has proven the damper is open. The outside air damper shall close 4sec (adj.) after the supply fan stops.

Alarms shall be provided as follows:

- Outside Air Damper Failure: Commanded open, but the status is closed.
- Outside Air Damper in Hand: Commanded closed, but the status is open.

Supply Fan:
The supply fan shall run anytime the unit is commanded to run. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime, unless shutdown on safeties.

Alarms shall be provided as follows:

- Supply Fan Failure: Commanded on, but the status is off.
- Supply Fan in Hand: Commanded off, but the status is on.
- Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).

Supply Air Temperature Setpoint - Outside Air Reset:
The controller shall monitor the supply air temperature and shall maintain supply air temperature setpoint. The supply air temperature setpoint shall reset for cooling as follows:

As outside air temperature drops from 85°F (adj.) to 20°F (adj.)
the supply air temperature setpoint shall reset upwards from 55°F (adj.) to 95°F (adj.).

Cooling:
The controller shall measure the supply air temperature and modulate the cooling to maintain its cooling setpoint. To prevent short cycling, there shall be a definable (adj.) minimum runtime.

The cooling shall be enabled whenever:

- ¶ The supply air temperature is above cooling setpoint.
- ¶ AND the fan status is on.

Dehumidification:
The controller shall measure the supply air humidity and modulate the dehumidification to maintain its humidity setpoint. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

The dehumidification shall be enabled whenever:

- ¶ The supply air humidity is above the humidity setpoint.
- ¶ AND the fan status is on.

Heating:
The controller shall measure the supply air temperature and modulate the heating to maintain its heating setpoint. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

The heating shall be enabled whenever:

- ¶ The supply air temperature is below heating setpoint.
- ¶ AND the fan status is on.

Final Filter Differential Pressure Monitor:
The controller shall monitor the differential pressure across the final filter.

Alarms shall be provided as follows:

- Final Filter Change Required: Final filter differential pressure exceeds a user definable limit (adj.).

Supply Air Temperature:
The controller shall monitor the supply air temperature.

Alarms shall be provided as follows:

- High Supply Air Temp: If the supply air temperature is greater than 120°F (adj.).
- Low Supply Air Temp: If the supply air temperature is less than 45°F (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Final Filter Differential Pressure	x								x		
Supply Air Temp	x								x		x
Freezestat			x						x	x	x
Outside Air Damper Status			x						x		x
Smoke Detector			x						x	x	x
Supply Fan Status			x						x		x
Cooling Modulation				x					x		x
Cooling %				x					x		x
Dehumidification Modulation				x					x		x
Dehumidification %				x					x		x
Heating Modulation				x					x		x
Heating %				x					x		x
Outside Air Humidity				x					x		x
Supply Air Humidity				x					x		x
Outside Air Damper				x					x		x
Supply Fan Start/Stop				x					x		x
Outside Air Temp					x						x
Supply Air Temp Setpoint					x				x		x
Emergency Shutdown						x			x	x	x
Schedule								x			

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Compressor Runtime Exceeded										x	
Final Filter Change Required										x	x
High Supply Air Temp										x	
Low Supply Air Temp										x	
Outside Air Damper Failure										x	
Outside Air Damper in Hand										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	
Supply Fan Runtime Exceeded										x	
Totals	**2**	**0**	**4**	**10**	**2**	**1**	**0**	**1**	**18**	**12**	**19**

Total Hardware (16) **Total Software (34)**

6. Chiller Manager (typical of 1)

Chilled Water System - Chiller Manager - Run Conditions:
The chilled water system shall be enabled to run whenever:

- A definable number of chilled water coils need cooling

To prevent short cycling, the chiller manager shall run for and be off for minimum adjustable times (both user definable).

Each chiller shall run subject to its own internal safeties and controls.

Chiller Staging - Two Equal Sized Chillers Running in Parallel:
This section refers to the staging and sequencing of each chiller "train". The sequence of operation for each individual chiller and its associated support equipment (such as pumps) are not included in this section.

The controller shall determine the facility cooling load and shall stage the chillers on in sequence to meet rising cooling demand and rising main chws temperature where:

- Load (in tons refrigeration) = [chwr temp (degrees F) - chws temp (degrees F)] x flow (gpm)] / 24.
- Load (in kW refrigeration) = [chwr temp (degrees C) - chws temp (degrees C)] x flow (liters/min)] / 14.36
- --Units shall be converted as required to reflect actual system of units used (metric or english)
- Main chws temperature is measured at a point leaving the chiller plant and entering the facility. This point shall be downstream and common to all chillers.

The controller shall determine the facility cooling load from:

- chws flow (main chws leaving chiller plant)
- chws temperature (main chws leaving chiller plant)
- chwr temperature (main chwr returning to chiller plant)

The following setpoints are recommended values. All setpoints shall be field adjusted during the commissioning period to meet the requirements of actual field conditions.

The lead chiller train shall run anytime the chiller manager is enabled. Additional chillers shall stage on as follows. To prevent short cycling, there shall be a user definable (adj.) delay between stages, and each stage shall have a user definable (adj.) minimum runtime.

¶

Second Chiller:
Stage ON if load rises above setpoint* of 60 tons (adj.)
OR chilled water supply temperature rises above setpoint of 52°F (adj.)
Stage OFF if load drops below setpoint* by 40tons (adj.)
AND chilled water supply temperature drops below setpoint by 3°F (adj.)

*Based on a percentage of the running chiller(s) combined capacity (adj. setpoints).

The chiller staging order shall be user definable. The designated lead, second and third chiller order (user definable) shall rotate upon one of the following conditions (user selectable):

- ¶ manually through a software switch
- ¶ if chiller runtime (adj.) is exceeded
- ¶ daily
- ¶ weekly
- ¶ monthly

Each chiller shall run subject to its own internal safeties and controls. On failure of any chiller, the failed chiller shall be "removed" from operation and the next available piece of equipment as defined by the user shall be staged on in its place.

Alarms shall be provided as follows:

- ¶ Chiller 1 Failure: Commanded on, but the status is off.
- ¶ Chiller 2 Failure: Commanded on, but the status is off.

- High Main Chilled Water Supply Temp: If the main chilled water supply temperature is greater than 56°F (adj).
- Low Main Chilled Water Supply Temp: If the main chilled water supply temperature is less than 38°F (adj.).
- High Main Chilled Water Return Temp: If the main chilled water return temperature is greater than 68°F (adj.).
- Main Chilled Water Return Temp: If the main chilled water return temperature is less than 47°F (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Main Chilled Water Return Temp	x								x		x
Main Chilled Water Supply Flow	x								x		x
Main Chilled Water Supply Temp	x								x		x
Outside Air Temp					x						x
Chiller 1 Failure										x	x
Chiller 2 Failure										x	x
Main Chilled Water Pressure										x	x
High Main Chilled Water Return Temp										x	
High Main Chilled Water Supply Temp										x	
Low Main Chilled Water Return Temp										x	
Low Main Chilled Water Supply Temp										x	
Totals	**3**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**3**	**7**	**7**

Total Hardware (3) **Total Software (11)**

7. Chilled Water Energy (typical of 1)

Chilled Water Cooling Demand - Energy Meter:
The controller shall monitor the chilled water supply temperature, chilled water return temperature and chilled water flow to the building and calculate current energy demand on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Invalid Reading: Sensor readings indicate an invalid demand value.

Peak Demand History:
The controller shall monitor and record the peak (high and low) demand readings from the chilled water energy meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Usage History:
The controller shall monitor and record chilled water energy 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**
Chilled Water Flow	x								x		x
Chilled Water Return Temp	x								x		x
Chilled Water Supply Temp	x								x		x
Demand					x				x		x
Peak Month-to-Date									x		x
Peak Today									x		x
Peak Year-to-Date									x		x
Usage Month-to-Date									x		x
Usage Today									x		x
Usage Year-to-Date									x		x
Totals	**3**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**10**	**0**	**10**

Total Hardware (3) **Total Software (11)**

8. Chiller Interface (typical of 1)

Chiller Interface Monitor:
Current chiller status and operating conditions will be monitored through its communications interface port. The interface will monitor and trend the points as shown on the Points List.

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Chilled Water Return Temp					x				x		x
Chilled Water Supply Temp					x				x		x
Chilled Water Supply Temp Setpoint					x				x		x
Chiller kW					x				x		x
Condenser Refrigerant Pressure					x				x		x
Condenser Water Return Temp					x				x		x
Condenser Water Supply Temp					x				x		x
Evaporator Refrigerant Pressure					x				x		x
Oil Differential Pressure					x				x		x
Oil Temp					x				x		x
Operating Hours					x						x
Chilled Water Flow Status						x			x		x
Chiller Status						x			x		x
Condenser Water Flow Status						x			x		x
Totals	**0**	**0**	**0**	**0**	**11**	**3**	**0**	**0**	**13**	**0**	**14**

Total Hardware (0) **Total Software (27)**

9. Electric Meter (typical of 1)

Electric Meter:
The controller shall monitor the electric meter for electric consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- ¶ Meter Failure: Sensor reading indicates a loss of pulse output from the electric meter.

Peak Demand History:
The controller shall monitor and record the peak (high and low) demand readings from the electric meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Usage History:
The controller shall monitor and record electric meter readings so as to provide a power consumption history. Usage readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Demand Levels:
The controller shall set the system demand level (adj.) based on the current power consumption readings from the electric meter. There shall be six daily time periods in which the demand shall be adjusted on three levels. These demand levels shall be available for facility equipment to utilize for demand limiting.

- ¶ Demand Level 1: Power consumption has exceeded the first demand level threshold (adj.).
- ¶ Demand Level 2: Power consumption has exceeded the second demand level threshold (adj.).
- ¶ Demand Level 3: Power consumption has exceeded the third demand level threshold (adj.).

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
kW Pulse	x										x
Current Demand Level					x				x		x
kW Demand									x		x
kW Peak Month-to-Date									x		x
kW Peak Today									x		x
kW Peak Year-to-Date									x		x

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
kWh Today									x		x
MWh Month-to-Date									x		x
MWh Year-to-Date									x		x
Demand Level 1										x	
Demand Level 2										x	
Demand Level 3										x	
Meter Failure										x	
Totals	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**8**	**4**	**9**

Total Hardware (1) **Total Software (13)**

10. Gas Meter (typical of 1)

Gas Meter:
The controller shall monitor the gas meter for gas consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- ¶ Meter Failure: Sensor reading indicates a loss of pulse output from the gas meter.

Peak Demand History:
The controller shall monitor and record the peak (high and low) demand readings from the gas meter. Peak readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Usage History:
The controller shall monitor and record gas meter readings so as to provide a gas 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**
Gas Flow Rate	x										
Demand									x		x
Peak Month-to-Date									x		x
Peak Today									x		x
Peak Year-to-Date									x		x
Usage Month-to-Date									x		x
Usage Today									x		x
Usage Year-to-Date									x		x
Meter Failure										x	
Totals	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**1**	**7**

Total Hardware (1) **Total Software (8)**

11. Outside Air Conditions (typical of 1)

Outside Air Conditions:
The controller shall monitor the outside air temperature and humidity and calculate the outside air enthalpy on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- Sensor Failure: Sensor reading indicates shorted or disconnected sensor. In the event of a sensor failure, an alternate outside air conditions sensor shall be made available to the system without interruption in sensor readings.

If an OA Temp Sensor cannot be read, a default value of 65°F will be used.

If an OA Humidity Sensor cannot be read, a default value of 50 % will be used.

Outside Air Temperature History:
The controller shall monitor and record the high and low temperature readings for the outside air. These 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**
Outside Air Humidity	x								x		x
Outside Air Temp	x								x		x
Outside Air Enthalpy					x				x		x
High Temp Month-to-Date									x		x
High Temp Today									x		x
High Temp Year-to-Date									x		x
Low Temp Month-to-Date									x		x
Low Temp Today									x		x
Low Temp Year-to-Date									x		x
Sensor Failure										x	
Totals	**2**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**9**	**1**	**9**

Total Hardware (2) **Total Software (11)**

12. Water Flow Meter (typical of 1)

Water Meter:
The controller shall monitor the water meter for water consumption on a continual basis. These values shall be made available to the system at all times.

Alarm shall be generated as follows:

- ¶ Meter Failure: Sensor reading indicates a loss of pulse output from the water meter.

Peak Demand History:
The controller shall monitor and record the peak (high and low) demand readings from the water meter. These readings shall be recorded on a daily, month-to-date, and year-to-date basis.

Usage History:
The controller shall monitor and record water meter readings so as to provide a water 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**
Water Flow Rate	x										
Demand									x		x
Peak Month-to-Date									x		x
Peak Today									x		x
Peak Year-to-Date									x		x
Usage Month-to-Date									x		x
Usage Today									x		x
Usage Year-to-Date									x		x
Meter Failure										x	
Totals	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**1**	**7**

Total Hardware (1) **Total Software (8)**

SECTION 23 09 20 - VARIABLE FREQUENCY DRIVES

PART 1 - GENERAL

1.01 DESCRIPTION

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

B. This specification is to cover a complete variable frequency motor drive (VFD) consisting of a pulse width modulated (PWM) inverter for use on a standard NEMA Design B induction motor.

1.02 QUALITY ASSURANCE

A. Referenced Standards

1. Institute of Electrical and Electronic Engineers (IEEE)
2. Standard 519-Latest Edition, IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
3. Underwriters Laboratories Inc.
   a. UL 508C
4. National Electrical Manufacturer’s Association (NEMA)
   a. ISC 6, Enclosures for Industrial Controls and Systems
   b. ISC 7.0, AC Adjustable
5. IEC 16800 Parts 1 and 2

B. Qualifications

1. VFDs shall be UL Listed.
2. VFDs shall be CUL Listed or CSA Approved.

C. VFD shall be manufactured in an ISO 9002 certified facility.

D. VFD shall be manufactured in accordance with ISO 14001 (Environmental Management Standard).

E. VFD shall meet the following vibration test standards: IEC 60068-2-29; 60068-2-64; 60068-2-6.

1.03 SUBMITTALS

A. Submittals shall include the following information:
1. Outline dimensions
2. Weight

1.04 WARRANTY

A. Warranty shall be 24 months from the date of certified start-up, not to exceed 30 months from the date of shipment. The warranty shall include all parts, labor, travel time, and expenses.

PART 2 - PRODUCTS

2.01 ADJUSTABLE FREQUENCY DRIVES

A. Manufacturers

1. Drives and all necessary controls, as herein specified shall be supplied by the drive manufacturer. Manufacturer shall have been engaged in the production of this type of equipment for a minimum of ten (10) years.
2. All drives on the project shall be by the same manufacturer.
3. Acceptable Manufacturers shall be: ABB, Emerson, Danfoss, Yaskawa, Siemens, Eaton or Square D.

B. General

1. Drives shall be designed specifically for variable torque applications.
2. The adjustable frequency drives shall be solid state, with a Pulse Width Modulated (PWM) output waveform.
3. The VFD package as specified herein shall be enclosed in a NEMA 1 enclosure (unless located outdoors; a NEMA 3R enclosure shall be furnished), completely assembled and tested by the manufacturer. The VFD shall employ a full wave rectifier (to prevent input line notching), DC Line Reactor, capacitors, and Insulated Gate Bipolar Transistors (IGBTs) as the output switching device, or the VFD shall consist of Matrix technology, where the input power stage converts three phase AC line power directly into variable AC output. The Main circuit shall consist of a compact input filter and bidirectional IGBT's. The bidirectional switches are input devices that carry the full current of the drive.
4. The drive efficiency shall be 97% or better at full speed and full load. Fundamental power factor shall be 0.98 at all speeds and loads.

C. Specifications for the 1 HP to 400 HP (550 HP w/o bypass) VFD at 480 Volts and 1 to 100 HP VFD at 230 Volts:

1. Input 440/460/480/500 VAC +/-10% (capable of operation to 624 VAC), 3-phase, 48 - 63 Hz or Input 208/220/230/240 VAC +/-10%, 3-phase, 48 - 63 Hz.
2. Output 0 - Input Voltage, 3-phase, 0 to 500 Hz for drives up to 75 HP; 0 to 120 Hz for drives over 75 HP. Operation above 60 Hz. shall require programming changes to prevent inadvertent high-speed operation.
3. Environmental operating conditions: 14 to 120^{o}F (-10 to 50^{o} C) @ 3 kHz switching frequency, 0 to 3,300 feet above sea level, less than 95% humidity, non-condensing.
4. Enclosure shall be rated UL Type 1.

D. All VFDs shall have the following standard features:

1. All VFDs shall have the same customer interface, including digital display, keypad and customer connections; regardless of horsepower rating. The keypad is to be used for local control, for setting all parameters, and for stepping through the displays and menus.
2. The VFD shall give the user the option of either 1) displaying a fault, 2) running at a programmable preset speed, 3) hold the VFD speed based on the last reference received, or 4) cause a Warning to be issued, if the input reference (4-20mA or 2-10V) is lost; as selected by the user. The VFD shall provide a programmable relay output for customer use to indicate the loss of reference condition.
3. The VFDs shall utilize plain English digital display (code numbers and letters are not acceptable). The LCD shall be backlit to provide easy viewing in any light condition. The contrast should be adjustable to optimize viewing at any angle. All set-up parameters, indications, faults, warnings and other information must be displayed in words to allow the user to understand what is being displayed without the use of a manual or cross-reference table. Keypad shall have a built-in time clock capable of month, day and time stamping faults.
4. The VFDs shall utilize pre-programmed application macros specifically designed to facilitate start-up. The Application Macros shall provide one command to reprogram all parameters and customer interfaces for a particular application to reduce programming time.
5. The VFD shall have the ability to automatically restart after an overcurrent, overvoltage, under voltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between reset attempts shall be programmable. If the time between reset attempts is greater than zero, the time remaining until reset occurs shall count down on the display to warn an operator that a restart will occur.
6. The VFD shall be capable of starting into a rotating load (forward or reverse) and accelerate or decelerate to setpoint without safety tripping or component damage (flying start).
7. The VFD shall be equipped with an automatic extended power loss ride-through circuit which will utilize the inertia of the load to keep the drive powered. Minimum power loss ride-through shall be one-cycle, based on full load and no inertia. Removing power from the motor is not an acceptable method of increasing power loss ride-through.
8. The customer terminal strip shall be isolated from the line and ground.
9. Pre-wired 3-position Hand-Off-Auto switch and speed potentiometer. When in “Hand,” the VFD will be started, and the speed will be controlled from the speed potentiometer. When in “Off,” the VFD will be stopped. When in “Auto,” the VFD will start via an external contact closure, and its speed will be controlled via an external speed reference.
10. The drive shall employ the following 3 current limit circuits to provide trip free operation:
    a. The Slow Current Regulation limit circuit shall be adjustable to 130% (minimum) of the VFDs variable torque current rating. This adjustment shall be made via the keypad, and shall be displayed in actual amps, and not as percent of full load.

b. The Rapid Current Regulation limit shall be adjustable to 170% (minimum) of the VFDs variable torque current rating.

c. The Current Switch-off limit shall be fixed at 175% (minimum, instantaneous) of the VFDs variable torque current rating.

11. The overload rating of the drive shall be 110% of its variable torque current rating for 1 minute every 10 minutes, and 130% of its variable torque current rating for 2 seconds every 60 seconds.

12. The VFD shall have input line fuses or circuit breakers standard in the drive enclosure.

13. The VFD shall have a DC Line Reactor to reduce the harmonics to the power line and to increase the fundamental power factor. Dual DC link chokes may be utilized as an acceptable alternate.

14. The VFD shall be optimized for a 4 kHz carrier frequency to reduce motor noise and provide high system efficiency. Carrier frequency shall be selectable for 1, 2, 4, 8, 10, or 12 kHz.

15. The VFD shall include a fireman's override input. This mode shall override all other control modes (analog, digital, serial and keypad commands) and the motor shall run at the preprogrammed speed. The keypad shall display "Override Mode" status. Upon removal of the override signal, normal operation shall be resumed.

E. All VFDs shall have the following adjustments:

1. Three (3) programmable critical frequency lockout ranges to prevent the VFD from continuously operating at an unstable speed.

2. PI Setpoint controller shall be standard in the drive, allowing a pressure or flow signal to be connected to the VFD, using the microprocessor in the VFD for the closed loop control.

3. Two (2) programmable analog inputs shall accept a current or voltage signal for speed reference or for reference and actual (feedback) signals for PI controller. Analog inputs shall include a filter; programmable from 0.01 to 10 seconds to remove any oscillation in the input signal. The minimum and maximum values (gain and offset) shall be adjustable within the range of 0 - 20 mA and 0 - 10 Volts. Additionally, the reference must be able to be scaled so that maximum reference can represent a frequency less than 60 Hz, without lowering the drive maximum frequency below 60 Hz.

4. Six (6) programmable digital inputs for maximum flexibility in interfacing with external devices. One (1) digital input is to be utilized as a customer safety connection point for fire, freeze, and smoke interlocks (Enable). Upon remote, customer reset (reclosure of interlock), drive is to resume normal operation.

5. Two (2) programmable analog outputs proportional to Frequency, Motor Speed, Output Voltage, Output Current, Motor Torque, Motor Power (kW), DC Bus voltage, or Active Reference.

6. Three (3) programmable digital relay outputs. The relays shall be rated for maximum switching current 8 amps at 24 VDC and 0.4 amps at 250 VAC; Maximum voltage 300 VDC and 250 VAC; Continuous current rating 2 amps RMS. Outputs must be true form C type contacts; open collector outputs are not acceptable.

7. Seven (7) programmable preset speeds.
8. Two (2) independently adjustable accel and decel ramps. These ramp times shall be adjustable from 1 to 1,800 seconds.
9. The VFD shall Ramp or Coast to a stop, as selected by the user.

F. The following operating information displays shall be standard on the VFD digital display. The display shall be in complete English words (alpha-numeric codes are not acceptable).

1. Output Frequency
2. Motor Speed (RPM, % or Engineering units)
3. Motor Current
4. Calculated Motor Torque
5. Calculated Motor Power
6. DC Bus Voltage
7. Output Voltage
8. Heatsink Temperature
9. Analog Input Values
10. Keypad Reference Values
11. Elapsed Time Meter
12. kWh meter

G. The VFD shall have the following protection circuits. In the case of a protective trip, the drive shall stop, and announce the fault condition in complete words (alpha-numeric codes are not acceptable).

1. Overcurrent trip 175% instantaneous of the VFDs variable torque current rating.
2. Overvoltage trip 130% of the VFDs rated voltage
3. Under voltage trip 65% of the VFDs rated voltage
4. Over temperature +176-194^{o}F (+80-90^{o}C)
5. Ground Fault either running or at start
6. Adaptable Electronic Motor Overload (I2t). The Electronic Motor Overload protection shall protect the motor based on speed, load curve, and external fan parameter. Circuits which are not speed dependent are unacceptable. The electronic motor overload protection shall be UL Listed for this function.

H. Speed Command Input shall be via:

1. Keypad.
2. Two (2) analog inputs, each capable of accepting a 0-20mA, 4-20mA, 0-10V, 2-10V signal. Input shall be isolated from ground, and programmable via the keypad for different uses.
3. Analog inputs shall have a programmable filter to remove any oscillation of the reference signal. The filter shall be adjustable from 0.01 to 10 seconds. The analog input should be able to be inverted, so that minimum reference corresponds to maximum speed, and maximum reference corresponds to minimum speed. The minimum and maximum values (gain and offset) shall be

adjustable within the range of 0 - 20 mA and 0 - 10 Volts. The active analog input shall have loss of reference protection, if selected.

4. Floating point input shall accept a 3-wire input from a Dwyer Photohelic (or equivalent type) instrument.

I. Serial Communications

1. The VFD shall have embedded Modbus RTU, BACnet, Siemens FLN and Johnson Metasys N2 protocols as standard for building automation systems network communications accessible via a RS-485 port.
2. Optional protocols shall include LonWorks, and Ethernet.
3. The VFD shall be able to communicate with PLCs, DCSs, and DDCs.
4. Serial communication capabilities shall include, but not be limited to, run-stop control, speed set adjustment, proportional/integral PI controller adjustments, current limit, and accel/decel time adjustments. The drive shall have the capability of allowing the Building Automation System (BAS) to monitor feedback such as output speed/frequency, current (in amps), % torque, % power, kilowatt hours, relay outputs, and diagnostic fault information.

J. Accessories to be Furnished and Mounted by the Drive Manufacturer

1. Customer Interlock Terminal Strip - provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external interlocks and start/stop contacts shall remain fully functional whether the drive is in Hand, Auto or Bypass.
2. All wires to be individually numbered at both ends for ease of troubleshooting.
3. Door interlocked thermal magnetic circuit breaker which will disconnect all input power from the drive and all internally mounted options. The disconnect handle shall be thru-the-door type, and be padlockable in the “Off” position.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Installation shall be the responsibility of the mechanical contractor. The contractor shall install the drive in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

B. The manufacturer must ensure that the installed THD is less than 5%. Should the voltage THD exceed 5%, the VFD manufacturer is to recommend the additional equipment required to reduce the voltage THD to an acceptable level.

C. Power wiring shall be completed by the electrical contractor. The contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.

1. VFD rated shielded cabling shall be provided between the drive and the motor.

D. When 6 pulse drives are used, provide dv/dt filters when the VFD is between 100 and 300 feet from the motor and provide sine wave filters when the VFD is over 300 feet from the motor.

3.02 START-UP

A. Certified factory start-up shall be provided for each drive by a factory authorized service center. A certified start-up form shall be filled out for each drive with a copy provided to the Owner, and a copy kept on file at the manufacturer.

3.03 TRAINING

A. The manufacturer shall provide on-site training for the Owner's maintenance personnel for a period of not less than four (4) hours. Training shall be provided for each different type of drive.

END OF SECTION

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SECTION 23 21 13 - PIPING AND ACCESSORIES

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

B. It should be noted that all products, piping, valves, fittings, and accessories specified in this section are for systems with maximum operating pressures of 150 psig in order to establish the type and quality of products required. Where the maximum operating pressure is greater than 150 psig in any system, furnish and install products, piping, valves, fittings, and accessories with pressure classifications that are suitable for the operating pressures. In general, all valves, fittings, and accessories below 350 feet of the highest piping point must have pressure ratings of 300 psig or greater. Above 351 feet and below 575 feet of the highest piping point pressure ratings shall be 500 psig or greater.

C. Piping and accessories installed indoors shall have a flame-spread index of 25 or less, and smoke-developed index of 50 or less.

D. Ensure that materials used for fire-stopping, caulking, sealing, pest/rodent proofing, etc. are compatible with the piping material used. Some materials are known to react with certain piping systems causing premature failure.

1.02 WORK INCLUDED

A. The work under this section shall include all labor, materials, accessories, services and equipment necessary to furnish and install all piping and accessories, complete, as indicated and specified herein.

B. Without limiting the generality thereof, the work in this section shall include the following items:

1. Piping
2. Hangers and Supports
3. Suction diffusers
4. Flexible connections
5. Thermometers
6. Pressure gauges
7. Combination pressure/temperature test ports
8. Heat cable for freeze protection of piping
9. Piping Identification
10. Painting of pipe
11. Expansion Compensation

C. Makeup water connections from the connection left under the Plumbing Section to the systems shall be the same as specified under Plumbing for Cold Water.

D. Piping shall be manufactured in the United States. Submit Certificate of Manufacture with shop drawings.

E. Submit a copy of the water quality analysis to illustrate the water quality at the project site.

1.03 RELATED WORK

A. Section 23 05 23 – VALVES FOR HVAC PIPING

B. Section 23 21 16 - HYDRONIC PIPING SPECIALTIES

1.04 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.
2. Fiberglass Pipe and Fitting Installers: Installers of reinforced thermosetting resin (fiberglass) fittings (RTRF) and reinforced thermosetting resin (fiberglass) pipe (RTRP) shall be certified by the manufacturer of pipe and fittings as having been trained and qualified to join fiberglass piping with manufacturer recommended adhesive.
3. Polypropylene Pipe and Fitting Installers: Installers of polypropylene piping shall be certified by manufacturer of pipes and fittings as having been trained and qualified to join polypropylene piping using fusion welding of the same type as specified in Drawings (socket, butt, eletrofusion, fusion outlet).

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.

PART 2 - PRODUCTS

2.01 PIPING

A. Refer to table below for pipe and fittings materials.

Branch piping connections may be made using welding nozzles such as Weldolets or Thredolets and manufactured by Bonney Forge & Tool Works or equal. All welding shall be in accordance with the Standard Manual of Pipe Welding Contractors National Association.

Bolted branch outlets, Mechanical-T™, as manufactured by Victaulic or engineer approved equal may be used in lieu of Weldolets and Thredolets in applicable sizes. Mechanical-T shall feature a locating collar that aligns and secures the outlet housing in the proper location. U-bolt straps are not acceptable.

B. Grooved joint couplings shall consist of two or more housings manufactured of ductile iron conforming to ASTM A536, zinc electroplated carbon steel bolts and nuts, and pressure responsive elastomer gasket. (Gasket grade shall be suitable for the intended service. Gasket shall be manufactured by the coupling manufacturer.)

1. Rigid Type: Couplings to be installation ready or advanced grooved system design, to provide rigidity and system support and hanging in accordance with ANSI B31.1 and B31.9. Victaulic Style 107, W07, 607, 905 or Apollo Shurjoint Z07, Z07N, or engineer approved equal.
2. Flexible Type: Couplings to be installation ready or advance grooved system design. Flexible couplings may be used in lieu of flexible connectors at equipment connections and per manufacturer's guidelines on expansion loops or seismic joints. Victaulic Style 177, W77, Apollo Shurjoint 7707, 7707N, C305 or engineer approved equal.
3. Flange Adapters: Flat Face, for direct connection to ANSI Class 125 or 150 flanged components. Victaulic Style 741, Apollo Shurjoint 7041 or engineer approved equal.

C. Final connections to equipment shall be made with unions, grooved joint couplings, or flanges.

D. Gaskets for flanged joints shall be 1/16" thick, suitable for the service.

E. Drain piping:

1. Condensate drains from cooling coils shall be trapped as detailed and routed to the nearest plumbing drain as indicated.
2. Drain piping from air intake plenums and drip pans shall be routed to the nearest plumbing drain and shall terminate with an elbow turned down into the drain.
3. Pump drip pan drains shall be Type "M" copper with wrought fittings.
4. Where indicated, Schedule 40 DWV PVC pipe, ASTM D1785, is acceptable. Install per ASTM D2321. Fittings: Schedule 40 DWV PVC, socket type fittings, ASTM D2665. Joints: Solvent joints for PVC, ASTM D2564. (PVC piping is not acceptable for waste piping receiving discharge higher than 130 °F.). Foam core PVC piping is not acceptable.
5. CPVC piping is not allowed for condensate drain piping from direct expansion equipment.

F. Chilled water and hot water supply and return piping systems in sizes up to 2" may be copper or stainless steel, using the Apollo"Press", Victaulic Vic-Press 304™, or the Viega

ProPress piping system of couplings, fittings, and valves, in lieu of threaded steel and soldered copper.

G. The city water piping to all HVAC equipment shall be Type "L" hard tempered copper with wrought copper fittings. It shall be installed as detailed on the plans and in compliance with the equipment manufacturer's recommendations. The water supply will be left by the plumbing subcontractor, extended and connected to the equipment by the HVAC subcontractor. This piping will be insulated to match that which the plumbing subcontractor supplies.

H. High points of each water main shall be fitted with an automatic or manual air vent. Low points of water systems shall be fitted with a ¾" drain valve with hose end connection.

2.02 ALTERNATE PIPING SYSTEMS

A. Polypropylene (PP-RCT) Pipe

1. Reference Documents
   a. ASTM F 2389-07 - Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems
   b. CSA B137.11 - Polypropylene (PP-R) Pipe and Fittings for Pressure Applications
   c. NSF/ANSI 14 – Plastic Piping System Components and Related Materials
2. Pipe shall be manufactured from a PP-RCT resin meeting the short-term properties and long-term strength requirements of ASTM F 2389. The pipe shall contain no rework or recycled materials except that generated in the manufacturer's own plant from resin of the same specification from the same raw material. All pipe shall be made in an extrusion process. Hydronic hot water and heating piping shall contain a fiber layer (faser) to restrict thermal expansion. All pipe shall comply with the rated pressure requirements of ASTM F 2389 (minimum permissible working pressure shall be 55 psi @ 160°F). All pipe shall be certified by NSF International as complying with NSF 14, and ASTM F 2389. Pipe shall be:
   a. Niron® Clima®, available from Nupi Americas, Inc. Piping specifications and ordering information are available at www.nupiamericas.com.
3. Fittings shall be manufactured from a PP-RCT resin meeting the short-term properties and long-term strength requirements of ASTM F 2389. The fittings shall contain no rework or recycled materials except that generated in the manufacturer's own plant from resin of the same specification from the same raw material. All fittings shall be certified by NSF International as complying with NSF 14, and ASTM F 2389 or CSA B137.11. Fittings shall be:
   a. Niron® PP-RCT as manufacturered by Nupi Americas. Fittings specifications and ordering information are available at www.nupiamericas.com.
4. Manufacturer shall warrant pipe and fittings for 10 years to be free of defects in materials or manufacturing. Warranty shall cover labor and material costs of repairing and/or replacing defective materials and repairing any incidental damage caused by failure of the piping system due to defects in materials or manufacturing. Warranty shall be in effect only upon submission by the contractor to the manufacturer valid pressure/leak test documentation indicating that the system was

tested and passed the manufacturer's pressure/leak test.

5. Valves shall be manufactured in accordance with the pipe manufacturer's specifications and shall comply with the performance requirements of ASTM F 2389. The valves shall contain no rework or recycled thermoplastic materials except that generated in the manufacturer's own plant from resin of the same specification from the same raw material. Valves shall be by:
   a. Niron® available from Nupi Americas and produced using manufacturer authorized materials.
6. Smoke and fire ratings - where plenum-rated piping is required, the pipe shall be wrapped and/or insulated with standard pipe insulation. The pipe wrap or insulation shall meet the requirements of ASTM E84. Insulation system shall have a composite insulation, jacket, binders, and adhesive Flame-Spread rating of 25 or less and a Smoke-Developed rating of 50 or less and shall be listed by UL.
7. Where the pipe is exposed to direct UV light for more than 30 days, provide a factory applied UV-resistant coating or alternative UV protection.
8. Provide expansion loops or devices as recommended by the piping manufacturer.
9. Refer to specification section 23 07 00 HVAC INSULATION for pipe insulation, coverings and coatings.

B. Copper Pressure-Seal-Joint Fittings:

1. Basis-of-Design Product: Subject to compliance with requirements, provide Apollo Press Fittings, made in the USA, or comparable product by one of the following:
   a. Viega ProPress
2. For Types K, L, and M hard copper tubing NPS ½ (DN 15) to NPS 4 (DN 100) and soft copper tubing in NPS ½ (DN 15) to NPS 1¼ (DN 32).
3. Housing: Copper or bronze.
4. Sealing Element: EPDM.
5. Multiple leak path detection system.
6. IAPMO PS-117.
7. Tools: Manufacturer's special tools.
8. Maximum 200 psig (1379 kPa) working pressure.
9. Maximum temperature rating at 250°F (121°C).
10. Maximum test pressures at 600 psig (4136 kPa).
11. Fittings for NPS 2 (DN 50) and smaller: Wrought-copper fitting with EPDM-rubber, O-ring seal in each end.
12. Fittings for NPS 2½ to NPS 4 (DN 65 to DN 100): Cast-bronze or wrought-copper with stainless-steel grip ring and EPDM-rubber, O-ring seal in each end.

2.03 PIPE AND FITTING MATERIALS:

PIPE AND FITTINGS SCHEDULE

SERVICE	SIZE	PIPE MATERIAL	FITTINGS	JOINTS	UNIONS	FLANGES	NOTES

CHILLED WATER HOT WATER	3/4" TO 2"	TYPE "L" COPPER ASTM B88	WROUGHT COPPER ASME B16.22	LEAD FREE SOLDER	COPPER TO COPPER GROUND JOINT ASME B16.22	N/A	
CHILLED WATER HOT WATER CONDENSER WATER	3/4" TO 2"	STD WEIGHT SCH 40 STEEL ASTM A53, GRADE B, TYPE E	CLASS 150 MALLEABLE IRON ASME B16.3	THREADED	CLASS 150 MALLEABLE IRON GROUND JOINT WITH BRONZE TO IRON SEAT - ASME B16.39	N/A	
CHILLED WATER HOT WATER CONDENSER WATER	2 1/2" TO 10"	STD WEIGHT SCH 40 STEEL ASTM A53, GRADE B, TYPE E	STD. WEIGHT BUTT WELD: WROUGHT STEEL ASME B16.9; GROOVED: DUCTILE IRON ASTM A536	BUTT WELDED OR GROOVED	N/A	CLASS 150 WROUGHT STEEL RAISED FACE SLIP-ON W/ FULL FACE GASKET ASME B16.9 ASTM A234 WPB	
CHILLED WATER HOT WATER CONDENSER WATER TEMPERED WATER	3/4" TO 4"	POLYPROPYLENE (PP-R) ASTM F2389-17a (SEE NOTE 5)	SOCKET FUSION	SOCKET FUSION	1/2" TO 2" BY PIPE MANUFACTURER, >2" N/A	SOCKET FUSION WITH FLANGE ADAPTER AND FULL-FACE RUBBER GASKET	SEE NOTE 5
CHILLED WATER HOT WATER CONDENSER WATER TEMPERED WATER	6" TO 24"	POLYPROPYLENE (PP-R) ASTM F2389-17a (SEE NOTE 5)	BUTT FUSION	BUTT FUSION	N/A	BUTT FUSION WITH FLANGE ADAPTER AND FULL-FACE RUBBER GASKET	SEE NOTE 5
CHILLED WATER HOT WATER TEMPERED WATER	3/4" TO 2"	CROSSLINKED POLYETHENE (PEX) ASTM F876 AND F877 (SEE NOTE 5)	COPPER CRIMP ASTM F1807, SS CLAMP ASTM F2098, COLD EXPANSIO	COPPER CRIMP ASTM F1807, SS CLAMP ASTM F2098, COLD EXPANSI	N/A	N/A	SEE NOTE 5

			N RINGS ASTM F1960	ON RINGS ASTM F1960			
CONDENSATE DRAIN	3/4" TO 3"	TYPE "M" COPPER ASTM B88 OR DWV ASTM B306	WROUGHT COPPER ASTM B16.29	SOLDER 50/50	COPPER TO COPPER GROUND JOINT	N/A	

NOTES:

1. REFER TO PIPING AND INSULATION SPECIFICATIONS FOR ADDITIONAL INFORMATION.
2. FOR HANGER AND SUPPORT SPACING, REFER TO PIPE HANGER SPACING TABLE.
3. PIPE, FITTINGS AND ACCESSORIES INSTALLED INDOORS SHALL HAVE A FLAME-SPREAD INDEX OF 25 OR LESS, AND A SMOKE-
   DEVELOPED INDEX OF 50 OR LESS.
4. FOR INSULATED PIPE, SIZE HANGERS TO INCLUDE INSULATION THICKNESS. PROVIDE COMPLETE SYSTEM (WITH INSTALLATION
   DETAILS) IN ACCORDANCE WITH THE LATEST EDITION OF THE NATIONAL COMMERCIAL AND INDUSTRIAL INSULATION STANDARDS MANUAL MICA PLATES OR MANUFACTURER'S RECOMMENDATIONS.
5. METALLIC PIPE SUPPORTS MUST BE INSTALLED PER THE MANUFACTURER'S LISTING IN ORDER TO ACHIEVE SMOKE DEVELOPED INDEX OF 50 OR LESS WHEN TESTED PER ASTM E84.
6. INSTALL PER ASTM D2774 – STANDARD PRACTICE FOR UNDERGROUND INSTALLATION OF THERMOPLASTIC PRESSURE PIPE.
7. FOAM CORE PVC IS NOT ACCEPTABLE.

2.03 PIPE SUPPORTS

A. All pipe supports, clamps, and inserts shall be provided under this section. Pipe hanger assemblies shall include turnbuckles or other means of vertical adjustment. Trapeze hangers may be used in lieu of separate hangers for closely spaced, parallel lines. Pipe hangers shall be as manufactured by Carpenter & Patterson, Inc., B-Line, Anvil Int'l, PHD Manufacturing, Inc. or approved equal. Product numbers used below are Carpenter and Patterson.

B. All piping above grade shall be supported by the building structure and shall not rest on ceiling tiles or the ceiling structure. Piping hung from joists shall be hung from the top chord of the joists.

C. Vertical runs shall be supported at the roof, each floor and at 10' intervals between floors.

D. Hangers for steel piping 2" and smaller shall be Figure 100 band type. Hangers for piping 2½" to 5" shall be Figure 100. Hangers for piping 6" and larger shall be Figure 100. Hangers shall have steel rods with two (2) nuts and shall be suspended from suitable beam clamps or concrete inserts.

E. Hanger spacing and rod sizes for single point support shall be per the table below:

HORIZONTAL PIPE SUPPORT SPACING*

Pipe Size	Maximum Horizontal Hanger Spacing in Feet (1)(2)				Minimum Rod Size (inches)
	Steel		Copper	PVC Sch 40	
	Water	Steam	Water	Condensate	
½	12	12	12	4	1/4
¾	12	12	12	4	1/4
1	12	12	12	4	1/4
1¼	12	12	12	4	3/8
1½	12	12	12	4	3/8
2	12	12	12	4	3/8
2½	12	12	12	4	3/8
3	12	12	12	4	3/8
4	12	12	12	-	1/2
5	12	12	12	-	1/2
6	12	12	12	-	1/2

*Spacing intervals comply with 2015, 2018 and 2021 IMC/IPC
(1) Spacing does not apply where span calculations are made or where concentrated loads are placed between supports such as flanges, valves, specialties, etc.
(2) IMC/IPC permits alternate support spacing per ANSI/MSS SP-58. For alternate support spacing refer to Horizontal Pipe Support Spacing - ANSI schedule.

F. Rod for trapeze hangers supporting several pipes shall be sized for the equipment load per manufacturer's recommendations.

G. Hangers for copper piping shall be similar to above for steel piping but where in contact with the copper piping, they shall be copper plated.

H. Hangers for insulated lines shall have insulation saddles and shields.

I. Pipe Vibration Hangers:

1. All piping attached to the building serving air handlers, air conditioners, pumps, chillers, etc., with rotating or pulsating parts shall be hung on spring type isolation hangers for at least 20 feet horizontally from where it attaches to any of the above. The spring hangers shall be capable of 1" deflection and when actually loaded, have at least ½" deflection.

J. Roof mounted pipe supports:

1. Condensate drain and refrigerant piping routed on the roof shall be supported with UV resistant rubber support system; Mifab C Series or equal by Dura-Blok.

2. Roof mounted piping shall be supported at 6’ intervals with pipe stands, framing systems, roller stands, curbs, etc. Support shall be provided at each change of direction and at branch take-offs. Submit layout drawings and product information during the submittal phase.

2.04 SLEEVES AND PLATES

A. All pipes passing through masonry walls shall be fitted with schedule 40 steel pipe sleeves. Sleeves shall be of the first possible size larger than the outside diameter of the pipe to be sleeved or the insulation jacket on covered pipes. Sleeves shall be flush on either side of the masonry walls.

B. All pipes passing through the masonry floors shall be fitted with schedule 40 steel pipe sleeves of the first size larger than the pipe to be sleeved. All sleeves on these floors shall extend 1" above the finished floor and 1" below the bottom of the slab. All pipe sleeves through the floors of the mechanical room shall be 16-gauge galvanized steel extending 2" above the finished floor. After the pipes are installed, the annular space shall be packed with fiberglass to ½" from the top of the sleeves, and then topped off with a ½" depth of sealant such as PRC-Rubber Caulk 7000 or other such approved sealant.

C. All exposed, uncovered pipes passing through walls or ceilings shall be fitted with chromium plated spun or split type escutcheons with a clamping device for holding the escutcheon in position.

D. All exposed uncovered pipes passing through floors shall be fitted with chromium plated spun or split type escutcheons which shall be high enough to cover the pipe sleeve and shall be fitted with a clamping device for holding the escutcheon in position and which shall rest upon the finished floor.

E. Piping entering the building below grade and passing through cast-in-place concrete walls or floors shall be fitted with a mechanical rubber seal inside of a 12" long schedule 40 steel pipe sleeve with integral water-stop. The sleeve shall be sized to house the mechanical rubber seal and carrier pipe. The mechanical rubber seal shall be constructed of EPDM and stainless-steel hardware and provide a hydrostatic seal of up to 20 psi and up to 40 feet of head. Products shall be Metraseal as manufactured by The Metraflex Company or equal by Link-Seal.

2.05 SUCTION DIFFUSERS

A. Suction diffusers shall consist of an angle type body with screwed, flanged or grooved connections sized to mate with the pump suction connection.

B. The suction diffuser shall have an integrated flow cone, carbon steel (stainless steel for open piping systems) straightening vane and a combination diffuser-strainer-orifice cylinder with 3/16" diameter openings for pump protection. The unit shall include a disposable 16 mesh bronze strainer which shall be removed after system start-up.

C. Unit shall be equipped with factory installed pressure/temperature test ports on the suction and discharge connections to allow for measurement of differential pressure across the

suction diffuser. Manufacturer's literature shall include a performance chart with the total pressure drop across the unit for each size installed.

D. Unit shall be fitted with a blowdown connection on the bottom of the casing to facilitate cleaning without removing the cylinder orifice.

E. Orifice cylinder shall be designed to withstand pressure differential equal to pump shut-off head and shall have a free area equal to five times the cross-sectional area of the pump suction opening. Vane length shall be no less than 2½ times the pump connection diameter.

F. Suction diffusers shall be equipped with an adjustable support foot to carry the weight of the suction piping.

G. Suction diffusers shall be rated as follows:

1. Threaded and flanged: 175 psi (1,207kPa) maximum working pressure and 250°F (121°C) maximum working temperature.
2. Grooved: 300 psi (2,068 kPa) maximum working pressure and 250°F (121°C) maximum working temperature.

H. Provide an extra set of O-rings for start-up and strainer removal.

I. Approved manufacturers: Bell & Gossett, Armstrong, Taco, Grundfos, or equal that meets or exceeds these specifications.

2.06 PRESSURE GAUGES

A. Pressure gauges shall be furnished and installed at the suction and discharge connections of each pump, at each coil, or piece or equipment in the system exclusive of accessories.

B. Gauges shall be 4½" diameter with metal case, bronze movement, bronze bourdon tube and brass ring. Gauges shall be accurate within 1% over the entire scale. All gauges shall have "T" handle cocks.

C. Gauges shall have a dial range that will provide a reading at maximum design operating pressure of between 50% and 75% of the dial range. Systems that will go into a vacuum shall also read 0" to 30" of vacuum.

D. Gauges shall be so placed as to be easily readable from the floor.

E. Gauges shall be manufactured by Weiss, Winters, Trerice or approved equal.

2.07 THERMOMETERS

A. Thermometers shall be furnished and installed at each coil or piece or equipment in the system exclusive of accessories unless shown otherwise

B. Thermometers shall be adjustable angle front reading red mercury type with 12" scale. Case shall be cast aluminum.

C. Angle adjustment shall utilize two positive locking set screws.

D. Furnish thermometers of temperature range suited for systems in which they are installed.

E. Thermometer wells shall be the full immersion type matched to thermometer stem length.

F. Furnish thermometers and accessories as manufactured by Weiss, Winters, Trerice or approved equal, at each piece of equipment that has a temperature change in a fluid.

2.08 COMBINATION PRESSURE/TEMPERATURE TEST PORTS (P/T PORTS)

A. Where indicated (unless integral with valves or specialties), provide combination pressure/temperature ports (Pete's Plug II or equal by Caleffi).

B. Test port shall have a ¼" fitting to accept either a temperature or pressure probe with a 1/8" OD fitting. Ports shall be solid brass with two valve cores of Neoprene rated for 500 psi at a maximum of 200°F and fitted with a gasketed color coded cap and strap.

C. At project close-out, present a complete portable test kit to the owner's representative. The kit shall consist of one pressure gauge (0-100 psi [700kPa] range) with a number 500 (1/8"x1½") probe pressure gauge adapter attached, one thermometer (25-125°F range), one thermometer (0-220°F range), an additional number 500-gauge adapter, and a protective carrying case with foam inserts.

2.09 FLEXIBLE CONNECTIONS

A. Furnish and install flexible connections in the piping at all equipment subject to movement or vibration.

B. Fittings materials of construction and end fitting type shall be consistent with pipe material and equipment/pipe connection fittings. Copper fittings shall not be attached to stainless steel hose.

C. Types:

1. Flexible metal hose connectors
    a. Flexible hose connectors shall be manufactured complete with an inner section of Type 304 stainless steel corrugated metal hose and an outer Type 304 stainless steel braid with inlet and outlet connections (threaded up to 2½" pipe size and flanged 3" and larger pipe size).
    b. Flexible hose connectors shall accommodate thermal expansion, contraction or seismic movement of the piping system and shall be capable of compensating for lateral movement and vibration.
    c. Minimum working pressure shall be 220 psi at 70°F

2. Connectors shall be Model SST (threaded) or Model SLT (flanged) as manufactured by The Metraflex Company or equal by Flex-Hose Company, Inc.
3. Spherical rubber connectors
   a. Rubber connectors/expansion joints shall be of the molded twin spherical type constructed of EPDM with an internal steel anchor wire molded within the raised face ends for added strength. An external steel root ring shall be located between the spheres for additional reinforcement.
   b. Spherical rubber connectors shall accommodate thermal expansion, contraction or lateral movement of the piping system and attenuate impeller generated noise transmitted through the pipe wall.
   c. Spherical rubber connectors shall be pressure rated for 150 psi at 200°F (2" thru 12" sizes) and 95 psi at 200°F (14" thru 20" sizes) with a minimum 4 to 1 safety factor.
   d. Flanges shall be one-piece, free-floating, class 150 galvanized plate steel type with tapped or drilled holes as required.
4. Connectors shall be “Doublesphere” as manufactured by The Metraflex Company or equal by Flex-Hose Company, Inc.
5. Spherical rubber connectors with control rods:
   a. Control Units must be provided in unanchored applications where additional safety factors are required to limit excessive movement or as recommended by the manufacturer.
   b. Control Units shall be as described above for Spherical rubber connectors, but with the following additional features:
      1) Integral cable restraints permanently affixed to the flanges to prevent over-extension.
      2) Control cables shall be of the galvanized aircraft type, and be an integral part of the joint requiring no field adjustment.
   c. Control units shall be “Double Cablesphere” as manufactured by The Metraflex Company or equal by Flex-Hose Company, Inc.

D. At a minimum, flexible connections shall be provided at connections to cooling towers, chillers and base mounted pumps.

E. At the Contractor’s option, the use of a minimum of three (3) flexible type grooved couplings may be substituted for flexible connections. Couplings shall be placed in close proximity to the source of the vibration. Consult coupling manufacturer for proper installation requirements.

F. Where piping crosses building expansion joints, provide spherical rubber connectors as specified above.

2.10 HEAT CABLE FOR FREEZE PROTECTION OF PIPING

A. Provide electric heat tracing on all exterior make-up and chilled water piping above grade.

B. The cable shall consist of 16 AWG nickel plated bus wires, tinned copper braid and modified polyolefin jacket.

C. Electric heat cable shall be installed linearly along the bottom of the pipe and allowance shall be made for all fittings, valves, pipe supports, etc. Cable shall be installed prior to insulation of the piping system.

D. Electric cable shall be capable of maintaining a minimum water temperature of 40 degrees F at an ambient air temperature of 0 degrees F.

E. The electric cable shall be the self-regulating type which responds to varying localized temperature conditions by varying the heat output along its length. This shall be accomplished by a self-regulating core which varies its resistance continuously with changes in temperature. A constant wattage heater is unacceptable.

F. Provide a thermostat control which de-energizes the heating cable when the ambient air temperature is above 40 degrees F (adjustable). While energized, the heat cable shall be entirely self-regulating.

G. Provide all power connection hardware, splices, end seals, etc. to accomplish a complete installation. All hardware shall be by the same manufacturer as the cable.

H. Electric heating cable and accessories shall be UL Listed-718K Pipe Heating Cable and shall conform to all requirements of Division 26.

I. Voltage shall be as indicated on the electrical drawings. Power circuits shall include ground fault protection.

J. Electric heating cable shall be Raychem XL-Trace or approved equal.

K. For PP-R Piping: Heat Tracing or Freeze Protection: Installed on the pipe interior or exterior; suitable for use with plastic piping; and be self-regulating to ensure surface temperature of the pipe and fittings will not exceed 158^{o}F (70^{o}C).

2.11 PIPING IDENTIFICATION

A. A marker showing the service and an arrow indicating the direction of flow shall be applied on the following piping installed under this section of the Specifications:

1. Condenser water
2. Chilled water
3. Hot water
4. Auxiliary condenser water
5. Tempered water (heat pump loop)
6. Steam (with pressure rating)
7. Condensate Return (with pressure rating)
8. Condensate Drain

B. Piping shall be labeled at each wall penetration (both sides), risers, equipment and each change of direction.

1. For general facility piping, straight runs of piping shall be labeled at intervals not greater than 50 feet and congested areas not greater than 20 feet.
2. For healthcare facilities, straight runs of piping shall be labeled at intervals not greater than 20 feet.

C. The letter size and background color shall conform to ANSI/ASME A13.1 Standard for the Identification of Piping Systems.

D. The labeling system shall consist of UV resistant vinyl tapes and labels suitable for indoor/outdoor use be as manufactured by Seton, Brady, or DuraLabel by Graphic Products.

2.12 EXPANSION COMPENSATION

A. Expansion in piping systems shall be compensated for by the use of u-bends, z-bends, spring isolators, expansion joints or flexible hose connectors as indicated. U-bends, z-bends and flexible hose connectors shall be complete with pipe guides and anchors.

B. Grooved piping systems may be used for expansion loops per manufacturer's guidelines.

C. Expansion joints shall be either bellows type or slip type suitable for the application in which installed.

1. Bellows type expansion joints shall be manufactured by Metraflex, Mercer Rubber Co., Flexicraft or approved equal.
2. Slip type expansion joints shall be manufactured by Hi-Span, Yarway, Advanced Thermal Systems or approved equal.

D. All vertical risers subjected to thermal expansion and/or contraction shall incorporate one of the following designs:

1. Spring type isolators and central anchor system designed to insure loading within design limits at structural support points.
   a. The riser design must be prepared and submitted for approval by the same isolation vendor supplying the HVAC mechanical equipment vibration isolation equipment.
   b. The submittal must include the initial load, initial deflection, change in deflection, final load and change in load at all spring support locations.
   c. In order to minimize load changes, the initial spring deflection must be at least four (4) times the thermal movement. The submittal must also include anchor loads when installed, cold filled, and at operating temperature. Include calculated pipe stress at end conditions and branch take-off locations.
   d. The submittal shall include complete layout drawings, product information and installation instructions.
   e. The submittal must be stamped and signed by a licensed professional engineer in the employ of the vibration equipment vendor for a minimum of five (5) years.

f. Proper provisions shall be made for seismic protection in applicable seismic zones.
g. The isolation vendor shall provide and design all brackets at riser spring and anchor locations where standard clamps lack the capacity or do not fit in the space allowed.
h. Install and adjust all isolators under the supervision of the designing isolation equipment vendor or his authorized representative.
i. The support spring mounts shall be Type SLF, the anchors Type ADA, and telescoping guides Type VSG, all as manufactured by Mason Industries, Inc.

2. Flexible hose expansion loop system manufactured complete with two parallel sections of corrugated metal hose, compatible braid, 180 degree return bend, and inlet and outlet connections. Field fabricated loops are not acceptable.
a. Flexible loops shall be capable of movement in the ±X, ±Y, and ±Z planes.
b. Flexible hose expansion loops shall impart no thrust loads to system support, anchors or building structure.
c. Flexible hose expansion loops shall be manufactured in accordance with the documented manufacturer's weld procedure specifications. The procedure qualification record shall be used to document the execution of this procedure and shall follow the general "guidelines" of ASME Section IX.
d. The manufacturer shall submit dimensioned layout drawings showing anchor loads (cold filled and operating temperatures), anchor and guide locations, support points and fastening methods.
e. The submittal shall include installation instructions.
f. Proper provisions shall be made for seismic protection in applicable seismic zones.
g. The submittal must be stamped and signed by a licensed professional engineer in the employ of the manufacturer for a minimum of five (5) years.
h. Corrugated hose and braid shall be constructed of Type 304 stainless steel. Fitting materials of construction and connection fitting type shall be consistent with pipe material and equipment/ pipe connection fittings.
i. Flexible hose expansion loops shall have a factory supplied, hanger/ support lug located at the bottom of the 180 degree return section.
j. Flexible hose expansion loop(s) shall be furnished with a 3/8" plugged FPT to be used for a drain or air release vent.
k. Flexible hose expansion loops shall be Metraloop as manufactured by The Metraflex Company or equal by Flex-Hose Company, Inc.

E. All vertical PVC condensate piping risers in buildings shall have expansion fittings to allow for building shrinkage compensation. The fitting shall be equal to Fernco Expansion Joint Model XJ. Expansion fitting shall be documented specifically for shrinkage of building materials and thermal expansion/contraction.

1. Wood framed buildings shall have a fitting in the first-floor ceiling space and every other floor thereafter.
2. Concrete buildings shall have a fitting in the first-floor ceiling space and every 8 floors thereafter.

3. All building stacks shall utilize riser pipe clamps at each floor.

PART 3 - EXECUTION

3.01 INSTALLATION

A. The Drawings are diagrammatic and the final arrangement of the work shall suit field conditions, the characteristics of the materials used and the instructions of the Engineer. Verify all dimensions in the field. Access and clearances must be provided and maintained for the proper operation, maintenance service and repair of the work.

B. Install in the piping all automatic control valves, thermometer wells, and like apparatus furnished by the temperature control manufacturer.

C. Hangers shall be arranged to maintain the required grading and pitch of piping, to prevent vibration and to provide for expansion and contraction.

D. Each vertical line shall be supported at its base using a suitable hanger placed in the horizontal line near the riser, unless otherwise noted, for base elbow support.

E. Grooved Piping Systems:

1. Grooved joints shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove. Use grooved fittings, couplings, valves, and specialties of a single manufacturer. Grooving tools shall be of the same manufacturer as the grooved components.
2. Grooved joint installer training: Contractor shall ensure each coupling installer has been trained on-site by a direct employee of the grooved manufacturer in the use of grooving tools, application of groove, and product installation. Contractor shall submit to the engineer documentation signed and dated by grooved manufacturer, showing the names of the installers that have completed jobsite training.
3. Grooved joint manufacturer inspections: A manufacturer's direct employee shall perform periodic inspections and provide a report to the engineer. Couplings installed that are not per manufacturer's guidelines will need to be replaced at the contractor's expense.
4. All grooved components shall conform to local code approval and/or as listed by ANSI-B-31.1, B-31.3, B-31.9, ASME, UL/ULC, FM, or IAPMO.
5. Grooved end product manufacturer to be ISO-9001 certified.
6. Certification Training:
    a. The installing contractor shall be certified by the grooved coupling manufacturer for the installation of their product. A manufacturer's factory trained representative (direct employee) shall provide on-site certification training for the installing contractor's field personnel in the use of grooving tools, application of groove, and product installation.
        1) A field training program must be designed, developed, administered and evaluated in accordance to the ANSI/IACET Standard for Continuing Education and Training. (IACET-International Association for Continuing Education and Training)

2) All installation professionals and pipe fitters must be able to provide proof of successful course completion upon request.

7. Inspection Services: A factory trained inspector (direct employee) shall visit the job site and review grooved joint products installation. The installing contractor shall remove and replace any improperly installed products.
8. Upon completion of the manufacturer's inspection of the installation, the manufacturer may supply the owner with an extended warranty on the products at the manufacturer's discretion.

F. Stainless steel pipe shall be certified for use with the Vic-Press 304™ piping system. Pipe shall be square cut, +/-0.030", properly deburred and cleaned. Mark pipe ends at the required location using a manufacturer supplied gauge to ensure full insertion into the coupling or fitting during assembly. Use a Victaulic "PFT" series tool with the proper sized jaw for pressing.

G. Copper Press Piping Systems:

1. Copper Press joints shall be clean and free from scarring. Use press fittings, valves and specialties from a single manufacturer. Press tools must be approved for use by manufacturer.
2. Copper Press installer training: Contractor shall ensure each press installer has been trained on-site by a direct employee of the press fittings manufacturer in the use of press tools, and product installation. Contractor shall submit to the engineer documentation signed and dated by press fitting manufacturer, showing the names of the installers that have completed jobsite training.
3. Press fitting manufacturer inspections: A manufacturer's direct employee shall perform periodic inspections and provide a report to the engineer. Press Fittings installed that are not installed per the manufacturer's guidelines shall be replaced at the contractor's expense.
4. All press components shall conform to local codes and/or as listed by ANSI B-31.1, B-31.3, B-31.9, ASME, UL/ULC, FM, IAPMO or ICC.
5. The press fitting product manufacturer is to be ISO-9001 certified.

H. Alternate Piping Systems

1. Install listed pipe materials and joining methods below in the following applications:
   a. Underground Piping: Polypropylene (PP-R) piping in SDR 7.4, 9, 11, or 17.6 per manufacturer's instructions and ASTM D2774.
   b. Aboveground: Polypropylene (PP-R) piping in SDR 7.4, 9, 11, or 17.6 based on the required minimum pressure rating and use temperature, in accordance with manufacturer's instructions and ASTM F2389.
2. Fusion welding of joints:
   a. Install fittings and joints using socket-fusion, elecrofusion, or butt-fusion as applicable for the fitting or joint type. All fusion-weld joints shall be made in accordance with the pipe and fitting manufacturer's specifications and product standards.
   b. Fusion-weld tooling, welding machines, and electrofusion devices shall be in accordance with the manufacturer's installation instructions.

c. Prior to joining, the pipe and fittings shall be prepared in accordance with F 2389 and the manufacturer's installation instructions.

d. Joint preparation, setting and alignment, fusion process, cooling times and working pressure shall be in accordance with the pipe and fitting manufacturer's installation instructions.

3. Piping installations

a. Install pipe hangers and supports at intervals specified in the applicable Plumbing or Mechanical Code and as recommended by the piping manufacturer.

b. Support vertical piping at each floor and as specified in the applicable Plumbing or Mechanical Code. Piping 2" or smaller shall be installed with mid-story guides per piping manufacturer's installation instructions.

c. Fire stopping shall be provided to be compatible with both the Aquatherm Piping and the requirements of ASTM E 814, "Standard Test Method for Fire Tests of Penetration Firestop Systems". The pipe insulation or fire resistive coating shall be removed where the pipe passes through a fire stop and, if required by the firestop manufacturer, for 3 inches beyond the firestop outside of the fire barrier.

d. When installed in systems with pumps in excess of 7.5 HP, piping shall be protected from excessive heat generated by operating the pump at shut-off conditions. Where the possibility exists that the pump will operate with no flow, the protection method shall be a temperature relief valve or comparable level of protection, set to a maximum temperature of 185°F.

e. If heat tracing or freeze protection is specified for the piping, it should be installed on the pipe interior or exterior, and it must be suitable for use with plastic piping and self-regulating to ensure the surface temperature of the pipe and fittings will not exceed 158°F.

f. Prior to insulating or covering, all piping shall be pressure/leak tested per manufacturer's recommendations. Tests shall be performed using water, compressed air or a mixture of the two. The test pressure shall be 1.5 times the operating pressure or 150 psi, whichever is greater. Any leaks detected shall be repaired by removing the leaking part and replacing with new parts welded per the pipe manufacturer's installation instructions.

4. Inspecting and cleaning:

a. Flush piping with cold water after the installation is completed. Inspect and test piping systems following procedures set forth by the authority having jurisdiction and in accordance with the piping manufacturer's installation instructions.

3.02 TESTING OF PIPING

A. Supply all materials, labor, and power required for testing. Make preliminary tests and prove work satisfactory. Notify the Engineer in ample time to be present for final testing of all piping. Tests shall be made before insulation or concealing any piping.

B. Repair defects disclosed by tests or, if required by the Engineer, replace defective work with new work without additional cost to the Owner. Repairs to piping systems shall be made with new material. No caulking of screwed joints, cracks or holes will be accepted.

Make tests in stages to facilitate work of others. Use of wicking in tightening leaking joints is not permitted.

C. The Contractor shall be responsible for work disturbed or damaged by tests and/or repair and replacement of his work and shall cause work so disturbed or damaged to be restored to its original condition at no additional expense to the Owner.

D. Unless otherwise specified, all piping shall be hydrostatically tested to 150 psi. Tests shall be of 2-hours duration during which time piping shall show no leaks and during which time no sealing of leaks will be permitted. Any equipment not capable of withstanding test pressures shall be suitably isolated from test pressure.

E. For PP-R Piping: Hydrostatic testing and documentation of test results for polypropylene piping shall be in accordance with the manufacturer's written instructions and submitted to the manufacturer upon successful completion per warranty requirements.

3.03 PAINTING

A. Prior to insulation being applied, clean pipe and fittings of all rust, dirt, grease, etc. and coat rusted areas with a rust preventative paint “Rust Destroyer” by Advanced Protective Products, Inc., or approved equal. Also, refer to Section 23 00 00 - HVAC General for painting of ferrous hangers and supports.

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SECTION 23 21 13.13 - PRE-INSULATED UNDERGROUND PIPING SYSTEM

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. The requirements of the General Conditions, Supplementary Conditions, and Section 23 00 00 - HVAC General apply to all work specified in this section.

B. The scope of work described in these Specifications and/or indicated on the Drawings shall include (except where otherwise noted) the furnishing of all materials, equipment, appurtenances, accessories, connections, labor, etc. required and/or necessary to completely install, clean, inspect, adjust, test, balance and leave in safe and proper operating condition all mechanical systems. All mechanical work shall be accomplished by workmen skilled in the various trades involved.

1.02 APPROVED MANUFACTURERS

A. Perma-Pipe Xtrutherm Plus, Niles, IL; Insul-8 Steel Pipe System by Rovanco Piping Systems, Inc., Joliet, Illinois; or equal by Therma-Cor Process, Inc., or equal by Aquatherm. Any alternate supplier must submit their technical data to the Architect ten (10) days prior to bid date to be considered for approval. The manufacturer shall submit complete product information highlighting specification paragraphs that show their product meets or exceeds the basis of design product. The pre-insulated pipe manufacturer shall design the system in accordance with ANSI B31.1, latest edition. The operating conditions shall be as follows: Chilled water 45^{o} The design shall include all layout drawings, stress calculations and complete product data.

PART 2 - PRODUCTS

2.01 STEEL PIPING SYSTEM FOR CONDENSATE, CHILLED OR HOT WATER, FUEL OIL, AND PROCESS PIPING APPLICATIONS:

A. Carrier Pipe - A-53 Grade B ERW in Schedule 40); or Aquatherm PP-R or PP-RP (RCT).

B. Insulation:

1. Polyurethane foam with the following minimum characteristics: K Factor 0.16, Density: 2 lbs/ft^3, Closed Cell Content: 90-95% in conformance with MIL-I-24172 and ASTM C-591 completely filling the annular space between the carrier pipe and jacketing. No voids will be allowed, manufacturer shall submit independent third party inspection reports for all systems that are foam injected to insure that they are void free. Minimum insulation thickness shall be in accordance with the table below. The insulation shall have an aluminum diffusion barrier applied to the outer layer of foam insulation prior to the HDPE jacket being applied. Systems that use foam injection and cannot install the aluminum barrier must supply a minimum SDR 32 HDPE jacket to slow the diffusion.

C. Jacketing Material:

1. On all straight sections, the jacket shall be high impact, seamless HDPE, minimum 100 mils, unless the manufacturer cannot install an aluminum diffusion barrier, then the manufacture shall use SDR 32 HDPE jacket material

Nominal Pipe Size in Inches	Minimum Insulation Thickness in Inches	Nominal Jacket Size OD in Inches	Jacket Thickness in Mils with Diffusion Barrier	Jacket Thickness in Mils without Diffusion Barrier
½	1	3 ½	100	0.206
¾	1	3 ½	100	0.206
1	1	3 ½	100	0.206
1 ¼	1	4 ½	100	0.138
1 ½	1	4 ½	100	0.138
2	1	5	100	0.165
2 ½	1 ½	6	100	0.204
3	1 ½	7	100	0.219
4	1 ½	8	100	0.265
5	1 ½	10	100	0.331
6	1 ½	10	100	0.331

D. Joining Method:

1. Straight lengths of pipe shall be joined by welding.

E. Fittings:

1. All fittings shall be factory fabricated. Taping and fitting covers in the factory will not be allowed. Only molded or extrusion welded HDPE jacket or FRP reinforced jacket will be allowed.

F. Insulation of Straight Joints:

1. Only welds on straight sections of pipe will be allowed. The foam shall be visually inspected prior to installation of shrink wrap material. The manufactures supplied shrink wrap shall be rated for 176°F (80°C); the shrink wrap thickness shall be a minimum of 0.90mm. All field joints shall be sealed per manufacturer's standard procedures.

G. Anchors:

1. A ½″ thick steel anchor plate shall be welded to the internal pipe and sealed to the pipe jacketing per system supplier's recommendations. The anchor assembly shall have no exposed metal. The anchor shall be completely isolated from the earth using a shrink wrap sleeve. No painted metal anchor plates will be allowed.

H. Backfill:

1. Clean backfill shall be placed in 6" layers with each layer tamped compactly in place so as to assure a stable surface. No rock shall be allowed in the backfill. A minimum cover of 24 inches, from top of the pipe jacket to grade. Compacted fill shall meet AASHTO H-20 Highway Loading.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install pre-insulated underground piping system in strict accordance with manufacturer’s recommendations. The pre-insulated pipe manufacturer shall have a factory trained representative on site, for a minimum of two (2) site visits, to instruct and review the contractor’s installation. The field technician shall submit a written report for each site visit to the architect.

B. Include all pre-insulated fittings, expansion joints, couplings, thrust blocks, supports, etc. to provide a complete system.

3.02 TESTING

A. Piping shall be tested with 150 psi of water with no decrease in pressure over a 2-hour period.

B. Test piping prior to insulating joints.

C. For PP-R Piping: Hydrostatic testing and documentation of test results for polypropylene piping shall be in accordance with the manufacturer's written instructions and submitted to the manufacturer upon successful completion per warranty requirements.

END OF SECTION

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SECTION 23 21 16 - HYDRONIC PIPING SPECIALTIES

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

1.02 WORK INCLUDED

A. Receipt, unloading, handling, proper storage and protection from damage of all materials.

B. Layout and coordination of work with other trades.

C. The work under this section shall include all labor materials, accessories, services, and equipment necessary to furnish and install all water specialties, as indicated and as specified herein.

PART 2 - PRODUCTS

2.01 EXPANSION TANKS

A. For each closed hydronic system, furnish and install vertical expansion/compression tank(s) of the capacity shown and specified herein. Acceptance volume shall be 100%.

B. The tank shell shall be fabricated from carbon steel and be designed and constructed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division I.

C. The tank shall be fitted with a replaceable heavy-duty Butyl rubber bladder to isolate the air from the system fluid.

D. Tanks shall be factory charged to 12 psi and complete with lifting rings, system connection fitting (NPT), a 0.302"-32 charging valve (Schrader valve) and drain connection (NPT). Tanks shall be provided with a rust inhibitive factory prime coat. Vertical tanks shall have a steel floor mounting skirt.

E. Tanks shall be rated for 125 psig maximum working pressure and 270°F maximum operating temperature.

F. Insulate tank(s) with 1" fiberglass insulation. Refer to Section 23 07 00 HVAC Insulation for additional information.

G. In areas requiring seismic restraint, provide manufacturer’s standard seismic restraint model. Install in accordance with manufacturer’s recommendations and local codes.

H. Expansion tanks shall be Bell & Gossett Series B Full Acceptance Pre-Charged Bladder Tank or equal by Taco, Wessels Co., or Armstrong provided they meet or exceed these specifications.

2.02 AIR AND DIRT SEPARATOR

A. For chilled and any other closed loop or hybrid closed/open loop water system, provide a full flow coalescing type combination air eliminator and dirt separator. Selection shall be based upon system flow with pipe size shown as a minimum. In no case shall the entering velocity exceed 6 feet per second

B. The shell shall be fabricated from carbon steel and designed, constructed, inspected and stamped in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division I. The unit shall be rated for 125 psig maximum working pressure and 270°F maximum operating temperature. The exterior of the shell shall be primed with a rust preventative paint and finished in an enamel coating.

C. The unit shall include internal coalescing elements filling the entire vessel to suppress turbulence and provide an air elimination efficiency of 100% free air, 100% entrained air, and 99.6% dissolved air at the installed location. Dirt separation efficiency shall be a minimum of 80% of all particles 30 microns and larger within 100 passes. The elements shall consist of a copper core tube with continuous wound copper wire medium permanently attached and followed by a separate continuous wound copper wire permanently affixed.

D. The vessel shall have two equal chambers above and below the inlet/outlet nozzles. The vessel diameter and height above and below the inlet/outlet connections shall be equal to the basis of design.

E. Each unit shall have a separate venting chamber to prevent system contaminants from harming the float and venting valve operation. At the top of the venting chamber there shall be an integral full port float-actuated brass venting mechanism. Units shall also include a valved side tap (skimmer valve) to flush floating dirt or liquids and for quick bleeding of large amounts of air during system fill or refill.

F. Do not make welds or other attachments to any part of the air separator.

G. Factory Options/Accessories:

1. Removable lower upper head for servicing internal components

H. Basis of design shall be Spirovent Series VDT or VHT as manufactured by Spirotherm, Inc. or approved equal. Optional Series VDN or VHN shall include removable lower head for internal inspection when scheduled. Equal products by Bell & Gossett, Caleffi, Armstrong, Taco and Amtrol will be considered provided they meet or exceed these specifications.

2.03 PRESSURE REDUCING VALVES

A. Pressure reducing valves shall meet the requirements of ASSE Standard 1003; (ANSI A112.26.2), CSA Standard B356 and be Certified by NSF to ANSI/NSF Standard 61-8.

B. Construction for sizes ½" thru 2" shall be:

1. Body: Lead Free copper silicon alloy
2. Seat:
   a. ½" thru 1" (15–25mm): Replaceable engineered polymer (10% glass filled Noryl)
   b. 1¼" thru 2" (32–50mm): Replaceable stainless steel
3. Integral Strainer: Stainless steel
4. Diaphragm: Reinforced EPDM with PTFE wetted surface
5. Valve Disc: EPDM
6. Temperature Range: 33°F – 160°F (0.5°C – 71°C)
7. Maximum Working Pressure: 300psi (20.7 bar)
8. Adjustable Reduced Pressure Range: 25 – 75psi (172 – 517 kPa)
9. Standard Reduced Pressure Setting: 50psi (345 kPa)

C. Acceptable manufacturers (provided they meet or exceed these specifications): Watts, Bell & Gossett, Apollo, and Cash Acme.

2.04 SAFETY RELIEF VALVES

A. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.

B. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.

C. Construction for sizes ¾" and 1" shall be:

1. Body: Bronze/Brass
2. Diaphragm and Seat: EPDM
3. Internal wetted parts: Brass
4. Maximum Working Pressure: 125 psig (8.6 bar)
5. Maximum Operating Temperature 250°F (121°C)

D. Construction for sizes 1½" and 2" shall be:

1. Body: Cast Iron
2. Diaphragm and Seat: EPDM
3. Internal wetted parts: Brass
4. Maximum Working Pressure: 50 psig (3.4 bar)
5. Maximum Operating Temperature 250°F (121°C)

E. Acceptable manufacturers (provided they meet or exceed these specifications): Watts, Bell & Gossett, Apollo, and Cash Acme.

2.05 AIR VENTS

A. Air vents shall be installed at the high points of closed loop hydronic piping systems.

B. Air vents shall be the serviceable type for inspection and replacement of internal components.

C. Air vents shall be fitted with either an integral check valve, integral shut-off valve or external shut-off valve to allow servicing without draining the system.

D. Construction for sizes ¼" thru ½" shall be:

1. Body: Brass
2. Float: Polypropylene or polyethylene
3. Mechanism stem: Brass
4. Mechanism Seal: EPDM
5. Seals: EPDM
6. Maximum Working Temperature: 240°F (115°C)
7. Maximum Working Pressure: 250psi (10 bar)
8. Maximum Vent Pressure: 60psi (4 bar)

E. Construction for size 3/4" shall be:

1. Body: Brass or Cast Iron
2. Float: Stainless Steel
3. Mechanism stem: Stainless Steel
4. Mechanism Seal: EPDM or Viton
5. Seals: EPDM
6. Maximum Working Temperature: 250°F (115°C)
7. Maximum Working Pressure: 230psi (10 bar)
8. Maximum Vent Pressure: 90psi (6 bar)

F. Acceptable manufacturers (provided they meet or exceed these specifications): Watts, Bell & Gossett, Caleffi, and Hoffman.

PART 3 - EXECUTION

3.01 INSTALLATION

A. All water specialties as herein specified shall be installed and adjusted to suit the system needs and requirements. The installation shall be performed in strict accordance with the manufacturer’s recommendations.

END OF SECTION

SECTION 23 21 23 - PUMPS

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. Furnish and install all pumps of the size, type, capacity and characteristics as shown on the equipment schedules and described herein.

B. Equipment schedules and specifications are based on the one manufacturer listed in the schedule. Other manufacturers of equal quality and performance may be submitted to the Engineer for review. When substitution of equipment is made, the Contractor shall be responsible for the costs of any item and engineering and construction revisions necessary in his or any other contract or trade that may be required to satisfy plans and specifications.

1.02 QUALITY ASSURANCE

A. Manufacturers: Firm regularly engaged in manufacturer of general-use centrifugal pumps with characteristics, pipe sizes and capacities required, whose products have been in satisfactory use in similar service for not less than five (5) years.

B. Manufacturers: Provide products produced by Bell & Gossett, Taco, Armstrong, Aurora or equal.

C. Electrical Standards: Provide electrical motors and products which have been listed and labeled by Underwriters Laboratories Inc. and comply with NEMA Standards.

D. Certification, Pump Performance: Provide pumps whose performance, under specified conditions, is certified by the manufacturer.

1.03 SUBMITTALS

A. Submit manufacturer’s data on pumps including but not limited to, pump characteristic performance curves, certified where indicated.

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver and store pump products in factory-wrapped packages which properly protect pumps against weather, dirt and damage.

B. Handle pumps carefully to avoid damage to motors, components, enclosures and finish. Do not install damaged units; replace and return damaged units to pump manufacturer.

PART 2 - PRODUCTS

2.01 PUMPS

A. Provide electrical motor driven, split case, volute type centrifugal pumps where indicated; base-mounted with single piece base. Equip with Class B insulated, quiet, drip-proof, ball bearing type motor of rotation speed, HP rating and power characteristics indicated (1750 RPM if not otherwise indicated); factory align and couple motor to pump. Provide pump rated for capacity, pressure and suction/discharge heads indicated. Equip pump with dynamically balanced, end suction enclosed type impeller, locked to pump shaft. Provide pump shaft with mechanical assembly, rotary type seal rated for water temperature of 250 degrees F. Connect pump to motor with flexible self-aligning coupling or close couple. Equip pump with sleeve bearings and force-feed lubrication system; and protect pump shaft internally with bronze sleeves. Provide bearing bracket assemblies of the type which can be removed without disturbing piping or motor. Impellers to be of non-overloading type so motor nameplate HP will not be exceeded at any point on the pump curve. The diameter of the impeller shall not exceed 85% of casing accommodation. Casings shall have drilled and tapped vent, drain and gauge openings.

2.02 MOTORS

A. Motors shall be heavy duty, high efficiency open drip proof unless otherwise specified. Motors shall meet Table MG-1-12C of EPACT ‘92.

B. Motors controlled by an adjustable frequency drive shall be compatible with the particular manufacturer’s drive that is used.

PART 3 - EXECUTION

3.01 INSPECTION

A. Installer must examine conditions under which pumps are to be installed and notify the Contractor in writing of conditions detrimental to proper and timely completion of work. Do not proceed with the work until unsatisfactory conditions have been corrected in a manner acceptable to installer.

3.02 INSTALLATION OF PUMPS

A. Install pumps where shown in accordance with manufacturer’s written instructions, and with recognized industry practices, to ensure that pumps comply with requirements and serve intended purposes. Comply with NEMA Standards and requirements of NEC.

B. Coordinate with other work (piping) as necessary to interface installation of pumps with piping and other components of water system.

C. Check alignment and, where necessary (and possible), realign shafts of motors and pumps within tolerances recommended by manufacturer.

D. Install units on pad mounts as shown; comply with manufacturer’s indicated installation method, if any, and with Division 23 sections.

3.03 ELECTRICAL CONNECTIONS

A. Ensure that pump units are wired properly, with rotation in direction indicated and intended for proper pump performance.

B. Provide positive electrical pump and motor grounding.

3.04 FIELD QUALITY CONTROL

A. Upon completion of installation of pump, and after motor has been energized with normal power source, bleed air from pump casing and test pump to demonstrate compliance with requirements. When possible, field correct malfunctioning units then retest to demonstrate compliance. Replace units which cannot be satisfactorily corrected.

END OF SECTION

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SECTION 23 23 00 - REFRIGERANT PIPING, INSULATION AND ACCESSORIES

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

B. Refrigerant piping shall meet the requirements of the Safety Standard for Refrigeration Systems (ANSI/ASHRAE Standard 15-Latest Edition) and the Code for Pressure Piping (ANSI/ASME Standard B31.5-Latest Edition: Refrigeration Piping and Heat Transfer Components).

C. Piping, valves, accessories, and insulation installed indoors shall have a flame-spread index of 25 or less, and smoke-developed index of 50 or less.

D. VOC Content: Submit adhesive and sealants product information or MSDS showing VOC content information for all applicable products specified under this section. All applicable products in this section must meet low VOC content as specified by LEED Specification Section 01 81 16: Facility Environmental Requirements. All work performed under this specification shall be accomplished in accordance with the requirements and provisions of the following sections:

1.02 WORK INCLUDED

A. The work under this section shall include all labor, materials, accessories, services, and equipment necessary to furnish and install all refrigerant piping, insulating systems, and accessories, complete, as indicated and specified herein.

B. Without limiting the generality thereof, the work in this section shall include the following items:

1. Direct expansion (DX) system piping (cooling only and heat pump)
2. Variable Refrigerant Flow/Variable Refrigerant Volume (VRF/VRV) system piping
3. Insulating the following systems:
    a. Refrigerant suction (low pressure gas) piping
    b. Refrigerant hot gas (discharge or high-pressure gas) piping
    c. Refrigerant liquid piping for VRF/VRV and Heat Pump systems
    d. Refrigerant liquid piping for ductless split systems

1.03 RELATED DOCUMENTS

A. Specification sections:

1. 23 81 28.12 Ductless Cooling Only Split Systems
2. 23 81 28.13 Ductless Split System Heat Pumps

3. 23 81 29 Variable Refrigerant Flow HVAC Systems

1.04 RELATED REFERENCES

A. Designation and Safety Classification of Refrigerants (ANSI/ASHRAE Standard 34-Latest Edition).

1.05 QUALITY ASSURANCE

A. Installer Qualification: Only trained and experienced installers skilled in refrigeration pipe installation, Copper-Tube, Pressure-Seal-Joint Fittings and brazing of copper tubing shall be used.

B. Piping, valves, and accessories shall be manufactured in the United States. Submit Certificate of Manufacture with shop drawings.

1.06 SUBMITTALS

A. Product Data: For each type of fitting, valve, and refrigerant piping specialty indicated. Include pressure drop based on manufacturer's test data.

B. Shop Drawings: Show layout of refrigerant piping and specialties, including pipe, tube, and fitting sizes, valve arrangements and locations, wall and floor penetrations, and equipment connection details. Show interface and spatial relationships between piping and equipment.

1. Refrigerant piping indicated on Drawings is schematic only. Size piping and design actual piping layout, including specialties, and pipe and tube sizes to accommodate, as a minimum, equipment provided, elevation difference between compressor and evaporator, and length of piping to ensure proper operation and compliance with warranties of connected equipment.

C. Piping materials including Certificate of Manufacture

D. Training certificates for installers of Copper-Tube, Pressure-Seal-Joint Fittings

E. Insulation products, adhesives, coatings, etc. including Material Safety Data Sheets

F. Field quality-control test reports

G. Operation and maintenance data

1.07 PRODUCT STORAGE AND HANDLING

A. Store piping, fittings, insulation, valves, and specialties in a clean and protected area.

B. Piping, tubes, and coils shall be stored with end caps in place to ensure that piping interior and exterior remain clean prior to installation.

PART 2 - PRODUCTS

2.01 REFRIGERANT PIPING

A. Piping shall be:

1. Type “L” hard drawn seamless copper tube conforming to ASTM B88, or
2. Type “ACR” (Air Conditioning and Refrigeration) service copper tubing conforming to ASTM B280.
   a. Straight Lengths: ASTM B 75, UNS C12200, H55 Temper (Light Drawn), ACR Bending Quality; Cleaned, Eddy Current Tested, and Plugged per ASTM B 280.
   b. Coiled: ASTM B 280, UNS C12200, O60 Temper (Soft Annealed), ACR, cleaned and capped. Coils shall be dehydrated, purged with Nitrogen, and tightly capped to insure cleanliness. Piping shall be engineered and constructed to support R-410A to 700 psi @ 250°F.

      1) Acceptable manufacturers:
         a) Streamline/Mueller
         b) Reftekk, Inc.
         c) Linesets, Inc.
         d) ACR Green Proshield by Select Manufacturing, Inc.
         e) JMF Company

B. Joints shall be brazed. Brazing filler metals shall comply with AWS A5.8.

C. Alternate piping/fitting connection system:

1. Copper-Tube, Pressure-Seal-Joint Fittings:
   a. Copper Press Fittings: Refrigerant Grade Copper (UNS C12200 min. 99.9% pure copper for body) for use with Type ACR, Hard Drawn Type K, and L, and Soft Annealed Type K, and L tubing compatible with ASTM Standards noted above.
      1) Continuous operating temperature: Minus 40°F to Plus 250°F (minus 40°C to plus 121°C).
      2) Maximum Rated Operating and Abnormal Pressure: 700 psi (48 bar/4800 kPa).
      3) Burst Pressure: >3X Maximum Operating and Abnormal Pressure: >2100psi/ >144 bar/ >14400 kPa).
      4) Vacuum Pressure Capability: 200 Microns.
      5) Leak Tightness: Helium $\leq 7.5 \times 10^{-7}$ Pa.m^3/s at +20°C and 10 bar.
   b. O-Rings: Factory installed Hydrogenated Nitrile Butadiene Rubber (HNBR) or material compatible with specific refrigerant used.
      1) Temperature Range: Minus 40°F to Plus 284°F (minus 40°C to plus 140°C). Temperature ratings may vary slightly.
   c. Warranty: 10-year manufacturer’s warranty for defects in material and workmanship.
2. Tools: Manufacturer’s approved jaw(s) and tool: Approved jaws display two circular 360 deg (400 g) press bands with circular groove on either side, along with a manufacturer’s witness mark embossed on the bands.

a. Maximum Allowable Working Pressure: In accordance with UL 207: 700 psig (48 bar).
b. Minimum Allowable Burst Pressure: In accordance with UL 207: 2100 psig (145 bar).

3. Basis-0f-Design Product: Subject to compliance with the requirements herein, RLS, LLC, Rapid Locking System Press Fittings.
   a. Acceptable alternate press fitting products:
      1) Mueller/Streamline ACR Copper Press Fittings
      2) ZoomLock MAX by Parker Hannifin, Sporlan Division

2.02 VALVES, FITTINGS AND SPECIALTIES

A. Fittings shall be wrought copper conforming to ASME/ANSI Standard B16.

B. Valves, filter-driers, and other accessories shall be suitable for refrigerant service.

C. Field Swaged Brazing Cups: MSS-SP-73, ASME B 16.50

D. Field Bends (all angles): ASME B31.5

E. Full Port Refrigeration Service Valves:
1. Body: Forged brass uni-body style with brass cap including key end to remove core
2. Schrader service valve with cap
3. Core: Removable ball-type check valve with stainless-steel spring
4. Seat: Polytetrafluoroethylene
5. End Connections: Socket ends
6. Working Pressure Rating: 700 psig (factory tested)
7. Maximum Operating Temperature 300°F
8. Valves must be specifically rated for R-410A
9. Approved manufacturers: Diamondback, Parker, RLS, Mueller/Streamline

2.03 INSULATION

A. Refrigerant piping shall be insulated as follows:

1. Refrigerant Piping Installed Outdoors: shall be insulated with flexible elastomeric tubing insulation with factory applied UV resistant durable protective jacket; Armaflex Shield™ continuous coil pipe insulation as manufactured by Armacell, LLC or alternates listed below, when the product is available in the required pipe size and insulation wall thickness (k-factor: 0.25 hr•ft²•°F/Btu (0.036 m²•°C/W) at 75°F (24°C) mean temperature). Polyethylene (PE) insulation is not acceptable. No field applied protective coating or finish shall be used with this insulation. Longitudinal and butt joints shall be sealed per manufacturer's installation instructions.
   a. Acceptable alternate elastomeric product:
      1) K-Flex USA; K-Flex Titan™ (k-factor: 0.23 hr•ft²•°F/Btu (0.035 m²•°C/W) at 75°F (24°C) mean temperature).
      2) Mueller Streamline Duraguard UV (k-factor: 0.242 hr•ft²•°F/Btu (0.035 m²•°C/W) at 75°F (24°C) mean temperature).

2. Refrigerant Piping Installed Indoors: shall be insulated with flexible elastomeric tubing insulation; AP/Armaflex Black LapSeal™ pipe insulation as manufactured by Armacell, LLC or alternates listed below (k-factor: 0.245-0.28 hr•ft²•°F/Btu (0.035 m²•°C/W) at 75°F (24°C) mean temperature). Polyethylene (PE) insulation is not acceptable. All joints and seams shall be sealed weathertight with Armaflex Black LapSeal™ Tape. Black LapSeal™ Tape shall also be used to secure the thermostat cable to the pipe insulation prior to applying the finish coat. The finish coat for this flexible elastomeric insulation when installed outdoors shall be two coats of a water-based latex paint designed for use over all forms of flexible elastomeric insulation. Finish coat shall provide a protective finish suitable to both indoor and outdoor applications, formulated for cold weather flexibility to resist cracking and weather-resistant to ultraviolet (UV) and ozone. Coating shall be Armaflex WB finish or equivalent product compatible with the insulation.
   a. Acceptable alternate products:
      1) Aeroflex, USA, Inc.; Aerocell-SSPT™ (k-factor: 0.245 hr•ft²•°F/Btu (0.035 m²•°C/W) at 75°F (24°C) mean temperature) with Protape and two coats of field applied Aerocel Aerocoat. (Aerocel Aerocoat required for outdoor installation only).
      2) K-Flex USA, LLC., K-Flex Insul-Lock DS (k-factor: 0.245 hr•ft²•°F/Btu (0.035 m²•°C/W) at 75°F (24°C) mean temperature) (indoor use only).
      3) Mueller Streamline elastomeric insulation (k-factor: 0.245 hr•ft²•°F/Btu (0.035 m²•°C/W) at 75°F (24°C) mean temperature) (indoor use only).
3. Fittings, valves, and specialties shall be insulated with factory formed sectional units of the materials listed above.
4. Insulation that is outdoors and not directly exposed to sunlight (i.e., piping is enclosed in a prefabricated duct system) does not require the UV protective coating.
5. Insulating systems above are to be considered as a minimum. Air conditioning system manufacturer's recommendations take precedence over the insulation materials listed above. Submit air conditioning manufacturer's installation instructions and insulation product data for review and approval.

B. Insulation thickness shall be as follows:

ALL CODE VERSIONS

1. VRF/VRV Heat Pump and Heat Recovery Systems - Insulate all piping:
(Note that some ductless split systems and multi-split systems may operate at these temperatures. Verify operating temperatures with the manufacturer)

VRF/VRV Refrigerant Piping Systems										
REFRIGERANT CONDITION or PHASE	REFRIGERANT TEMPERATURE RANGE	INSULATION MEAN RATING TEMPERATURE	ACR TUBING OUTSIDE DIAMETER							
			1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1-1/8	1-3/8	1-5/8"
			INSULATION THICKNESS REQUIRED (INCHES)								

	(°F)	(°F)									
HIGH PRESS VAPOR	141-200	125	1-1/2”	1-1/2”	1-1/2”	1-1/2”	1-1/2”	1-1/2”	1-1/2”	1-1/2”	2”
LIQUID	105-140	100	1”	1”	1”	1”	1”	1”	1”	1”	1-1/2”
LOW PRESSURE VAPOR	40-60	75	1/2”	1/2”	1/2”	1/2”	1/2”	1/2”	1/2”	1/2”	1”
	BELOW 40	50	1”	1”	1”	1”	1”	1”	1-1/2”	1-1/2”	1-1/2”
NOTE: FOR PIPING SMALLER THAN 1-1/2 INCHES AND LOCATED IN PARTITIONS WITHIN CONDITIONED SPACES, REDUCTION OF THESE THICKNESSES BY 1 INCH SHALL BE PERMITTED, BUT NOT TO THICKNESSES BELOW 1 INCH.											

ASHRAE 90.1-2010, 2013, 2016, and 2019

1. Traditional Cooling Only Split Systems (TXV located at indoor unit) – Insulate suction piping only:
   a. All pipe sizes 1/2" insulation
2. Traditional Heat Pump Split Systems (TXV located at indoor unit) – Insulate suction piping only:
   a. <1-1/2" pipe 1" insulation
   b. 1-1/2"<4" pipe 1-1/2" insulation
3. Mini-Split Cooling Only (TXV located at outdoor unit) – Insulate all piping – 1/2" insulation
4. Mini-Split Heat Pump (TXV located at outdoor unit) – Insulate all piping – 1/2" insulation

PART 3 - EXECUTION

3.01 GENERAL

A. Refrigerant piping shall be supported as shown on the Drawings and as required at intervals not over 8'-0" O.C. and at all turns and offsets. Hangers and pipe clamps shall be copper plated tubing hangers of adequate size to fit around tubing and insulation as required. Saddles shall be used under insulated tubing to protect insulation. Piping routed more than 6 (six) lineal feet on the roof shall be supported by B-Line “Dura-Blok” rooftop supports or approved equal.

B. Pressure testing of piping systems shall be in accordance with standard industry practice for the refrigerant used.

C. Refrigerant piping shall be clean and free of outside contaminants at all times. Prior to start-up of any equipment or insulation installation, all piping shall be cleaned, tested, dehydrated and charged as recommended by the refrigerant compressor manufacturer.

1. Procedure: Joints and connections in refrigerant piping shall not be installed in partitions or walls or where inaccessible for testing, inspection and rework. Make provisions to prevent contact of dissimilar metals. During construction, cap all tubing to prevent moisture from entering. Keep in dry location.
2. Leak testing and recharging: Upon completion of installation of air conditioning equipment, test all refrigerant piping, components and accessories, including quick-connect refrigerant connectors for evaporator and condensing unit; test with a halide torch; prove tight by Contractor to assure a leak-tight refrigerant system. If leaks are detected at the time of installation or during warranty period, remove entire refrigerant charge from system, correct leaks, and retest system. After system is found to be leak free, evacuation shall be accomplished by use of a reliable gauge and a vacuum pump capable of pulling vacuum of at least one mm Hg absolute. Accomplish system evacuation in strict accordance with equipment manufacturer's printed instruction. System leak testing, evacuation, dehydration and charging with refrigerant shall comply with standard industry practice and local codes and ordinances.

D. Refrigerant piping shall be run continuously, without joints, where possible. All joints in refrigerant piping shall be made accessible. Joints shall not be permitted in concrete slabs or below grade.

E. Refrigerant circuit access ports located outdoors shall be fitted with locking-type tamper-resistant caps or shall be otherwise secured to prevent unauthorized access.

F. All piping shall be run true to grade and shall be arranged to make the best possible appearance. Except where otherwise required by conditions of installation, all piping shall be symmetrical and parallel with lines of buildings or structure in which it is installed. All piping shall be run concealed except in mechanical room and where indicated otherwise.

G. All piping and equipment shall be supported and guided. Anchors shall be provided to absorb or transmit thrust and eliminate vibration or pulsation. Hangers or supports shall be provided near each change of direction. Supports shall be so located or shall be of such type as not to unduly restrict the movement of the pipe due to lateral or longitudinal expansion.

3.02 PIPING APPLICATIONS

A. Suction (low pressure gas), Hot Gas (high pressure gas) and Liquid Lines 7/8" OD and Smaller for Conventional Air-Conditioning, Heat Pump, and Heat Recovery Applications: Copper, Type ACR, O60 (soft annealed)-temper tubing and field bent fittings with brazed joints.

B. Suction (low pressure gas), Hot Gas (high pressure gas), and Liquid Lines 2-1/8" OD and smaller for Conventional Air-Conditioning, Heat Pump, and Heat Recovery Applications:

Straight Lengths, Copper, Type ACR Type L, H55 (light drawn)-temper tubing and field bent fittings with brazed joints.

3.03 VALVE AND SPECIALTY APPLICATIONS

A. Install service valves as specified or as required to isolate system components.

3.04 PIPING INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems; route and size piping based on manufacturer's recommended line lengths and other design considerations. Install piping as indicated unless deviations to layout are approved on Shop Drawings.

B. Install refrigerant piping according to ASHRAE 15 (latest version).

C. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas. Concealed locations shall be free of pipe joints.

D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

F. Install piping adjacent to machines to allow service and maintenance.

G. Install piping free of sags and bends.

H. Field bend changes in direction.

I. Select system components with pressure rating equal to or greater than maximum allowable working pressure.

J. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.

K. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as specified in Division 08 Section "Access Doors and Frames" if valves or equipment requiring maintenance is concealed behind finished surfaces.

L. Provide jacketed insulation in locations where exposed to mechanical injury.

M. When brazing, remove solenoid-valve coils and sight glasses; also, remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.

N. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.

O. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 23 00 00 HVAC General.

P. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 23 00 00 HVAC General.

Q. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Division 23 00 00 HVAC General.

R. Provide proper compensation for pipe/tube expansion and contraction per equipment manufacturers recommendations.

3.05 PIPE JOINT CONSTRUCTION

A. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Chapter "Pipe and Tube".

1. Use Type BcuP-5 (15% Ag, 80% Cu, 5% P), copper-phosphorus alloy pre-formed brazing rings for joining copper swage fittings and copper socket fittings with copper pipe. Do NOT use flux.
2. Use Type Bag-5 (45% Ag), cadmium-free silver alloy for joining copper with bronze or steel. Use manufacturers recommended flux.

B. Field Swaged Brazing Cups: Fabricate brazing cup on one tubing end for each coupling. Only O60 (soft annealed) and H55 (light drawn) may be swaged. Do NOT swage H58 (drawn general purpose). Use swaging tool designed to provide a minimum of 0.0015" brazing gap and a maximum of 0.005" brazing gap. Brazing cup depth for each tube size shall be as follows:

1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1-1/8"	1-3/8"	1-5/8"	2-1/8"
0.250"	0.280"	0.310"	0.390"	0.420"	0.460"	0.510"	0.560"	0.600"	0.700"

C. Field Bends: Fabricate field bends with a center-line bend radius greater than or equal to 4 times the nominal OD of the pipe or tube. Tube shall be bent with a tubing bender sized for ACR OD tube sizes and shall not cause cracks or wrinkles in the tube or pipe. Do NOT use a conduit bender for bending ACR copper. The difference between maximum and minimum diameters for pipe bends should not exceed 8% of the nominal outside diameter of the pipe. Only O60 soft annealed-temper and H55 light drawn-temper shall be field bent. Do NOT field bend H58 drawn general purpose-temper copper tube.

D. Brazing and joining procedure:

1. Tube ends shall be cut with a clean sharp tubing cutter.
2. Deburr the I.D. of the cut tube end with a clean deburring tool.
3. Visually inspect the interior of each tube for obstructions and debris before assembly. Protect the joint from contamination before brazing.

4. Method of pre-cleaning: Non-shedding abrasive pads (Scotch Bright) to remove all oxides in the brazing area followed by wiping with a clean lint-free white cloth. Do not groove the surfaces while cleaning.
5. Purge all tubing with oil free nitrogen while brazing and until cool to the touch. Use an oxygen analyzer to verify the absence of oxygen prior to brazing. The oxygen content shall be less than 1% before start of brazing.
6. Use a neutral to slightly reducing flame using oxy/acetylene or oxy/propane.
7. Use the proper torch tip based on tube size as recommended by the torch manufacturer. Use of Turbo-Torch or Rosebud is permitted.
8. Post Brazing Cleaning: Exterior of all completed joints shall be washed with a water-soaked rag or sponge, followed by brushing with a stainless-steel hand wire brush to remove any residue for inspection.

C. Copper-Tube, Pressure-Seal-Joint Fittings:

1. Install fittings in strict accordance with manufacturer’s installation instructions.
2. Installers shall be trained and certified by the manufacturer.
3. Test piping system according to manufacturer's recommendations and prepare a test report to be turned over to the Owner for their records.

3.06 HANGERS AND SUPPORTS

A. Piping hangers and supports must accommodate expansion and contraction, vibration, dead load of piping and its contents, and seismic-bracing requirements.

B. Install the following pipe attachments or combination thereof:

1. Adjustable steel clevis hangers for individual horizontal runs.
2. Channel strut or angle iron trapeze for multiple horizontal runs
3. Galvanized steel saddle with attachment screw for channel strut applications
4. Rigid high compressive strength foam insulating pipe support at all clamps and support points.
5. Rigid high compressive strength foam pipe support at all riser clamps.
6. Do NOT attach hangers directly to pipe or tube.

C. Install hangers for copper tubing with the following maximum spacing and minimum rod sizes:

1. Up to 3/4" OD: Maximum span, 60 inches; minimum rod size, 3/8 inch.
2. Greater than 3/4" thru 1" OD: Maximum span, 72 inches; minimum rod size, 3/8 inch.
3. Greater than 1" thru 2-1/8" OD: Maximum span, 96 inches; minimum rod size, 3/8 inch.

D. Support multi-floor vertical runs every 10 feet and at least at each floor with riser clamps.

3.07 FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

B. Tests and Inspections:

1. Comply with ASME B31.5, Chapter VI.
2. Test as follows or as recommended by the equipment manufacturer's installation instructions:
   a. Line Test Pressure for Refrigerant R-410A:
      1) Suction (low pressure gas) Lines: 550 psig, or per equipment manufacturers recommendation.
      2) Hot-Gas (high pressure gas) and Liquid Lines: 550 psig, or per equipment manufacturers recommendation.
3. Test refrigerant piping and specialties. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
   a. Fill system with 95/5 nitrogen/hydrogen to the required test pressure.
   b. System shall maintain test pressure at the manifold gage throughout duration of test.
   c. Test all joints and fittings with hydrogen leak detector, at test pressure.
   d. Remake leaking joints using new materials, and retest until satisfactory results are achieved.

3.08 SYSTEM CHARGING

A. Charge system using the following procedures and per equipment manufacturer's installation instructions.

1. Evacuate (triple evacuation procedure) entire refrigerant system with a vacuum pump to obtain a steady state vacuum of less than 500 micrometers. If vacuum holds for 12 hours, system is ready for charging. Do NOT evacuate the system through a charging manifold. Use only suction rated hoses and core removal tools.
2. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
3. Charge system as recommended by equipment manufacturer.

3.09 OWNER REVIEW OF MAINTENANCE REQUIREMENTS

A. Review manufacturer's maintenance instructions with the owner's representative to make them aware of any reoccurring maintenance requirements such as recoating piping insulation, lubricating service valves, etc.

END OF SECTION

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SECTION 23 25 00 - HVAC WATER TREATMENT

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work in this section shall be subject to the provisions of Section 23 00 00 - HVAC General.

1.02 WORK INCLUDED

A. Furnish and install a complete water treatment system for each HVAC water system as indicated on the drawings and specified herein and including the following:

1. All closed loop systems (hot, chilled, and tempered water)

B. Include all controllers, piping, specialties, pumps, tanks, and all other equipment required for a complete fully functional and safe system for each HVAC water system.

C. Provide the services of an experienced water treatment company. Service provider shall be capable of analyzing water qualities, installing water treatment equipment, and applying water treatment as specified herein.

D. HVAC water treatment systems shall include, but not be limited to, the following:

1. Bypass chemical-feed equipment and controls
2. Biocide chemical-feed equipment and controls
3. Chemical treatment test equipment
4. HVAC water-treatment chemicals

1.03 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 the Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction. Water quality test shall be the responsibility of the Water Treatment Subcontractor.

1.04 SUBMITTALS

A. Submittal shall include concentration set points, flow diagram with all components indicated, and a draft of the contract agreement.

B. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for the following products:

1. Bypass feeders
2. Inhibitor injection timers
3. pH controllers
4. TDS controllers
5. Biocide feeder timers
6. Chemical solution tanks
7. Injection pumps
8. Chemical test equipment
9. Chemical material safety data sheets (MSDS)

PART 2 - PRODUCTS

2.01 GENERAL

A. Furnish and install apparatus to provide water treatment and service as furnished by Guardian-IPCO, Anderson Chemical Co., Nalco, GE Betz, NuCalgon, or Technical Specialties Corp.

1. All services and systems provided shall be provided by a single water treatment company.

B. A contract agreement satisfactory in form and substance to the Owner shall be executed between the subcontractor and the water treatment company through its authorized agents, binding the water treatment company to furnish supervisory service during the guarantee period to assure the use of the proper chemical treatment to and for the HVAC systems. The furnishing of the necessary chemicals for the treatment of the systems during temporary heating or cooling periods, including supervision of their use, shall be included in the Contract Agreement. The Contract shall be assigned to the Owner by the subcontractor on the date the building is accepted by the Owner so that water treatment will continue uninterrupted during the one-year life of the Contract. The water treatment company shall perform the following through its agents:

1. Install all water treatment systems and storage tanks.
2. Supervise the initial introduction of water treatment.
3. Provide service calls by its agents at a frequency of not less than once per 30 days thereafter.
4. Furnish all required chemicals for proper treatment of all systems together with all necessary testing equipment and reagents for field analysis of the water.
5. Supervise flush-out of all systems.
6. The subcontractor shall assume responsibility for the field testing and control and regular addition of chemical treatment in the amounts required of each of the systems until the date of final acceptance of the building by the Owner.

C. Control Ranges: All water treatment applied to any of the above-mentioned systems must be non-pollutant and meet all State and Federal Government regulations covering effluent disposal.

D. All piping associated with the water treatment systems shall be tested to the same pressure as the associated system.

E. The water treatment company shall design all piping sizes and flow rates for each specific application. All flow rates and pressure drops shall be within the capabilities of the system as designed.

2.02 CHILLED AND HOT WATER SYSTEMS

A. Liquid chemical bypass type one-shot feeder of 5-gallon capacity, complete with valves, fittings, and sight glass shall be connected across the piping of each hot and chilled water piping.

B. The shot feeder shall be located 12 inches above the floor. Manual ball valves shall be conveniently located adjacent the bypass feeder to isolate and drain the shot feeder. One ball valve shall have a memory stop set to keep a trickle flow through the shot feeder to keep valve seals wetted.

C. Water systems shall be treated with sufficient quantities of the proper chemicals to prevent corrosion damage and scale buildup.

2.03 FLUSH-OUT TREATMENT

A. After completion of the installation of the above systems, each system shall be flushed out prior to the start up of each system with the compounds furnished by the water treatment company. The flush-out compound shall be trisodium phosphate, 3% by weight. The solution must be circulated for 48 hours.

B. The flush-out treatment shall be applied to all of the above systems under the supervision of the water treatment company. Tests shall be made by the water treatment company following the chemical flush-out treatment, and a written report shall be submitted to the Architect stating that the cleaning and flushing has been completed satisfactorily. Chemical concentrations allowable after flush-out: phosphate, zero; alkalinity, 100 parts per million maximum; suspended solids, zero.

C. It shall be the responsibility of the subcontractor to coordinate between the pump manufacturer and the water treatment company and to arrive at a proper level of treatment to be maintained so as not to damage the pumps. The proper level of treatment shall be agreed upon by both parties.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install chemical treatment equipment in accordance with manufacturer's recommendations.

B. Store and handle chemicals in strict accordance with manufacturer's guidelines and all Federal, State, and local government regulations.

C. For each month during the first-year warranty period, test a sample from each cooling tower basin and the condenser water system for Legionella Pneumophila. A report shall be submitted to the building owner that indicates the bacteria per milliliter and the level from the previous month.

D. Furnish one test kit for the owner's use. The test kit shall contain all equipment and materials necessary to perform routine testing.

3.02 CLOSED LOOP SYSTEMS

A. Prior to adding cleaning chemicals to the closed loop system, all air handling unit coils, fan coil units, water source heat pumps, water cooled self-contained units, and water-cooled air conditioning units shall be isolated by closing the inlet and outlet valves and adding a temporary bypass around each coil or condenser.

3.03 SYSTEM START-UP

A. Prior to cooling tower start up, provide a passivation plan, and pretreat the cooling tower surfaces in accordance with the manufacturer's written instructions. Do not fill cooling tower with water without adding the appropriate treatment chemicals.

B. Provide written instructions for operating the water treatment system to the owner.

C. Demonstrate the water treatment system operation to the owner.

D. Provide all product data sheets, material safety data sheets, program control parameters, and log sheets to the owner.

E. Submit writing report of initial system sampling to the owner. At a minimum, the report shall include the following metrics:

1. Closed loop systems
    a. Iron
    b. Copper
    c. Conductivity
    d. Corrosion rates for copper and mild steel
    e. Nitrate level
    f. Microbial growth
2. Open loop systems

a. Iron
b. Copper
c. Conductivity
d. Corrosion rates for copper and mild steel
e. Microbial growth
f. Calcium hardness
g. Total alkalinity
h. Cycles of concentration
i. Inhibitor level

3.04 OWNERSHIP

A. All water treatment systems, equipment, and tanks shall be the property of the owner once they are installed.

END OF SECTION

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SECTION 23 31 00 - DUCTWORK AND ACCESSORIES

PART 1 - GENERAL

1.01 DESCRIPTION

A. All work in this section shall be subject to the provisions of Section 23 00 00 - HVAC General.

B. Furnish and install all material, labor, accessories, etc. shown on the drawings and as specified herein to completely install all ductwork systems.

C. Ductwork systems shall be classified as follows:

1. Static pressure class +2 in. wg - from constant volume air handling unit, and terminal unit to supply diffusers; all return, outside air and exhaust ductwork;

D. Refer to PART 3 – EXECUTION for duct sealing requirements.

E. Ductwork shall be constructed according to the latest edition of SMACNA ductwork construction standards applicable to the type of ductwork, system pressures described above, and the system material construction.

F. Duct sizes shown on the drawings are nominal inside clear.

1.01 RELATED DOCUMENTS

A. Specification sections:

1. 23 31 00 Fire Resistive Ductwork and Accessories
2. 23 35 33 Listed Kitchen Ventilation System Exhaust Ducts
3. 23 37 00 Louvers, Grilles, Registers and Diffusers
4. 23 51 00 Gas Vents, Flues, and Stacks

1.02 QUALITY ASSURANCE

A. Fire, smoke, combination fire/smoke and radiation dampers shall be installed and maintained in accordance with:

1. Manufacturer’s installation instructions
2. UL approved installation instructions and supplemental instructions
3. UL Damper Marking and Application Guide, latest edition
4. NFPA Standard 90A (latest edition)
5. SMACNA’s Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems (latest edition)

B. Control (balancing and shut-off) dampers shall be certified in accordance with:

1. AMCA Standard 500-D, Laboratory Methods of Testing Dampers for Rating

2. AMCA Publication 511, Certified Ratings Program – Product Rating Manual for Air Control Devices

C. Ductwork in food service establishments shall be in accordance with SMACNA's Food Grade Ductwork and Sheet Metal Guidelines.

1.03 SUBMITTALS

A. Product Data:

1. Duct materials:
   a. Fiberglass ductboard
   b. Outdoor duct systems
   c. Flexible duct connectors
   d. Flexible ductwork
2. Dampers and accessories
3. Remote damper operators
4. Access doors
5. Flexible duct connectors
6. Duct liner
7. Sealants, mastics, adhesives and coatings

B. For all fire dampers, combination fire and smoke dampers, and smoke dampers, submit UL approved installation instructions for each specific application.

PART 2 - PRODUCTS

2.01 DUCTWORK

A. Ductwork shall be constructed of galvanized steel sheets of the thickness listed in the SMACNA manuals for the pressures referenced above,

B. Single-Wall Rectangular Ducts and Fittings:

1. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
2. Transverse Joints: Select joint types and fabricate per SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," "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."
   a. Alternate Product: Subject to compliance with requirements, provide Ductmate Industries, Inc.; 25/35/45 Rectangular Flange System or comparable product by one of the following:
      1) Nexus PDQ; a division of Shilco Holdings, Inc.
      2) Ward Industries, Inc; a division of Hart & Cooley, Inc.
      3) Prior Approved Equal
   b. Slide-on Flanges:

1) Description: Roll-formed, add on, factory-fabricated, slide-on transverse flange connectors, gaskets, and components.
2) Material: galvanized steel.
3) Gauge and Shape: For duct constructed using prefabricated systems, refer to the manufacturer's guidelines for sheet gauge, intermediate reinforcement size and spacing, and proper joint reinforcement.
4) Manufacturers of prefabricated systems must provide duct construction and reinforcement guidelines along with independent testing for leakage, deflection, and seismic performance.
5) Independent leakage testing must be provided for systems operating at pressures of 10 in. wg (or greater) positive or negative.
6) Manufacturer's prefabricated systems printed assembly and installation procedures must be adhered to at all times.
7) Manufacturer's procedures must include fastener and cleat spacing along with details for all system variations including break-away and roofing connections.
8) All manufactured system components must be clearly embossed with manufacturer's name or markings. Substitution of manufacturer's system components is not permitted.

c. Formed flanges will be accepted on ductwork 42 inches wide or less and subjected to 2 in. wg static positive pressure or less.
1) Formed on Flanges: Construct as T-25 A/B flanges, of which construction guidelines are given in Figure 2-1 of the 2005 SMACNA “HVAC Duct Constructions Standards, Metal and Flexible.” No other construction standards pertaining to formed on flanges will be accepted.
2) Formed on flanges must include the use of corners, securely crimped in place, bolts, cleat, and gasket

3. Longitudinal Seams: Select seam types and fabricate per SMACNA's “HVAC Duct Construction Standards - Metal and Flexible,” “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.”
4. Snap-lock longitudinal duct seams are not allowed in public spaces unless secured with sheet metal fastening screws as recommended by SMACNA.
5. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate per SMACNA's “HVAC Duct Construction Standards - Metal and Flexible,” Chapter 4, “Fittings and Other Construction,” for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's “HVAC Duct Construction Standards - Metal and Flexible.”

C. Single-Wall Round and Flat-Oval Ducts and Fittings

1. 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.

a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1) Linx Industries
   2) McGill AirFlow, LLC
   3) SEMCO, LLC
   4) Sheet Metal Connectors, Inc.
   5) Spiral Manufacturing Co., Inc.
   6) Prior Approved Equal

2. 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).

3. Transverse Joints: Select joint types and fabricate per SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
   a. Transverse Joints in Ducts Larger Than 50 Inches in Diameter: Flanged.
      1) Unexposed Duct 3 inches to 30 inches in diameter: Round duct connects with a one-piece interior slip coupling at least two gages heavier than duct wall, beaded at center and fastened to duct with screws. Seal joint with an approved sealant applied continuously around both ends of coupler prior to assembling and after fastening.
      2) All Exposed Duct and Unexposed Duct 30 inches to 72 inches in diameter: Three-piece, gasket flanged-joint consisting of two internal flanges, with integral mastic sealant, and one external closure ring, for connecting the internal flanges and securing the closed cell neoprene gasketing in place.
         a) Basis-of-Design Product: Subject to compliance with requirements, provide Ductmate Industries, Inc.; Spiralmate or similar comparable product by one of the following:
            (1) Prior Approved Equal
      3) Ducts larger than 72 inches in diameter: Use companion angle flanged joints as defined in Figure 3-1 for the 2005 SMACNA Manual "HVAC Duct Construction Standards, Metal and Flexible" Third Edition. Refer to manual for proper sizing and construction details.
      4) Dust Collection Systems and Exposed Duct 3 inches to 14 inches in diameter: Use a one-piece, polyethylene lined gasket connector with integrated bolt for the closure system.
         a) Basis-of-Design Product: Subject to compliance with requirements, provide Ductmate Industries, Inc.; Quicksleeve or comparable product by one of the following:
            (1) Prior Approved Equal

4. Longitudinal Seams: Select seam types and fabricate per SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements,

materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

a. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.

b. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

5. Tees and Laterals: Select types and fabricate per SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Double-Wall Round and Flat-Oval Ducts and Fittings

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Linx Industries
   b. McGill AirFlow, LLC
   c. SEMCO, LLC
   d. Sheet Metal Connectors, Inc.
2. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct.
3. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.
   a. Transverse Joints: Select joint types and fabricate per SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
      1) Transverse Joints in Ducts Larger Than 50 inches in Diameter: Flanged.
         a) All Exposed Duct and Unexposed Duct 30 inches to 72 inches in diameter: Three-piece, gasket flanged-joint consisting of two internal flanges, with integral mastic sealant, and one external closure ring for connecting the internal flanges and securing the closed cell neoprene gasketing in place.
         b) Basis-of-Design Product: Subject to compliance with requirements, provide Ductmate Industries, Inc.; Spiralmate or comparable product by one of the following:
            (1) Prior Approved Equal
   b. Longitudinal Seams: Select seam types and fabricate per SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable

sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1) Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
2) Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.

c. Tees and Laterals: Select types and fabricate per SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

4. Inner Duct: Minimum 0.028-inch (24 gauge) perforated galvanized sheet steel having 3/32-inch diameter perforations, with an overall open area of 23 percent.
5. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard".
   a. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x ºF at 75ºF mean temperature.
   b. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
   c. Coat insulation with antimicrobial coating.
   d. Cover insulation with polyester film complying with UL 181, Class 1.
6. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.
   a. Maximum Thermal Conductivity: 0.25 Btu x in./h x sq. ft. x ºF at 75ºF mean temperature.

E. When detailed, round and oval ductwork shall be supported using galvanized wire rope cable and locking cable terminations. The locking cable terminations shall have an Ultimate Breaking Strength (U.B.S.) of at least 5 times the published Working Load Limit (W.L.L.). Wire ropes and locking cable terminations shall be sized, spaced, and furnished by the manufacturer. Submit layout drawings and product data during the submittal phase. Wire rope and locking cable terminations shall be Dynatite Suspension System as manufactured by Duro Dyne Corporation or Cable Shark as manufactured by Ductmate.

F. Rectangular sheet metal duct elbows shall be smooth radius type without turning vanes or square (or mitered) type with turning vanes. Sharp throat elbows (ASHRAE Fitting No. CR3-2) shall not be permitted. Round sheet metal duct elbows shall be smooth radius type without turning vanes, gored type or mitered type with turning vanes.

G. Unless otherwise indicated, elbows shall have a centerline radius of not less than 1½ times the width of the duct. Where space limitations necessitate use of short radius or square elbows, provide turning vanes.

H. Fiberglass duct board shall be UL 181 listed as a Class 1 Rigid Air Duct with a thermal conductivity not to exceed 0.23 at 75°F per ASTM C 518. Thickness shall be as indicated on the drawings or as required by the energy code in effect. Fiberglass duct board shall be

Johns Manville Super Duct RC, Knauf Atmosphere Air Duct Board, Owens Corning QuietR Duct Board or Certainteed Ultra*Duct Black Duct Board.

1. Tapes and mastics used to seal fibrous glass ductwork shall be listed and labeled in accordance with UL 181A and shall be marked “181A-P” for pressure-sensitive tape, “181A-M” for mastic or “181A-H” for heat-sensitive tape.

I. Exhaust ductwork shall be galvanized sheet metal (G 90 minimum) constructed to SMACNA standards and shall not be insulated unless noted otherwise.

J. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

K. Exterior supply and return air ductwork shall be constructed of galvanized sheet metal (G 90 minimum) lined with 2" thick 3 lb/ft^3 duct liner board (R-8 min. [R-12 min. in Climate Zones 5 through 8]); Johns-Manville Linacoustic R-300. All seams shall be externally sealed watertight with a 30-year silicone caulk and coated with a rust preventive coating over the entire duct surface. Rust preventative coating shall be “Rust Destroyer” by Advanced Protective Products, Inc., or approved equal. As an alternative to insulated sheet metal, an outdoor duct system as manufactured by Thermaduct, LLC may be used. The system shall incorporate duct and fittings having an installed minimum R-value of 8 [R-12 min. in Climate Zones 5 through 8]. The system shall utilize non-fibrous closed cell Kingspan KoolDuct fortified inner liner compliant to UL (C-UL) 181, Standard for Safety Listed, Class 1 system and SMACNA Class 1 leakage, or less. Submit product data and layout drawings during the submittal phase. Crown or slope ductwork at ¼" per foot transversely to prevent standing water on top of ductwork. For projects located within 2 miles of the seacoast, flanges and hardware shall be aluminum (alloy 3003 - H14 temper per ASTM B209).

L. Ductwork connecting kitchen exhaust hoods to exhaust fans shall be constructed of 16-gauge black steel with welded seams. All grease exhaust ductwork shall be constructed and installed according to requirements of local code authorities and NFPA 96 (latest edition) requirements. Slope duct down towards the hood at ¼" per linear foot up to 75 horizontal linear feet and at 1" per linear foot greater than 75 horizontal linear feet or per local code requirements. Access doors shall be provided as described below.

1. Alternate grease duct construction: factory-built grease duct system incorporating an integral fire-rated enclosure listed and labeled in accordance with UL 2221. The grease duct enclosure assembly and through-penetration firestop system shall be installed in accordance with the listing and manufacturer’s installation instructions. Refer to Section 23 35 33 Listed Kitchen Ventilation System Exhaust Ducts for additional requirements.

M. Kitchen hood exhaust ductwork shall be insulated per NFPA 96 (latest edition) and local code requirements (Re: Section 23 07 14 Fire Rated Insulation Systems). Kitchen hood supply ductwork shall be insulated per specifications for HVAC supply ductwork.

N. Dishwasher exhaust ductwork above the ceiling shall be either 18-gauge stainless steel (2D finish) or 16-gauge aluminum. All seams and joints shall be welded liquid tight.

O. Dishwasher exhaust risers and trim collars below the ceiling shall be 18-gauge, type 304 stainless steel finished in a 180-grit polished finish.

P. All dishwasher exhaust ductwork shall slope down toward the dishwasher connections at ¼" per linear foot and be constructed with no pockets which will trap condensation.

Q. Support roof mounted ductwork at 6 feet (max.) on center with Mifab Series DSA duct support system. UV resistant rubber bases shall be placed on roofing walk pad material. Coordinate with general contractor and roofing installer. Manufacturer shall submit layout drawings and product information during the submittal phase.

2.02 FLEXIBLE DUCTWORK

A. Flexible ducts shall be listed and labeled as UL Standard 181 Class 1 air duct. Air connectors are not allowed.

B. Flexible ductwork shall comply with the following:

1. NFPA 90A, “Installation of Air Conditioning and Ventilating Systems”
2. NFPA 90B, “Installation of Warm Air Heating and Air Conditioning Systems”
3. SMACNA's “HVAC Duct Construction Standards - Metal and Flexible” for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated.
4. Air Diffusion Council's “ADC Flexible Air Duct Test Code FD 72-R1”.
5. ASTM E 96/E 96M, "Test Methods for Water Vapor Transmission of Materials."

C. Flexible ductwork shall be installed between main supply ducts and diffusers. Length shall be a maximum of 8'-0" long, except in residential applications, where the length shall be as indicated.

D. Flexible ductwork shall be Thermaflex M-KE R-6 (R value = 6.0 minimum or as required by local energy code) flexible air duct or equal by Quietflex, Flexmaster, Atco, JP Lamborn, or Royal Metal Products. Provide R-8 when located outside the thermal envelope.

E. Flexible ductwork size shall be the same size as the diffuser neck it serves, unless indicated otherwise.

F. Take-offs for sheet metal ductwork shall be made using a conical spin-in type fitting with manual balancing damper.

G. Flexible duct connections to ceiling diffusers shall be installed without kinks or sags to provide unrestricted airflow. Provide Flex Flow Elbow supports by Thermaflex or FlexRIGHT elbow support by Build Right Products.

H. Tapes and mastics used to seal metallic and flexible air ducts shall comply with UL 181B and shall be marked “181B-FX” for pressure-sensitive tape or “181B-M” for mastic.

I. Mechanical fasteners for use with flexible nonmetallic air ducts shall comply with ul 181b and shall be marked “181B-C”.

2.03 LIFE SAFETY DAMPERS

A. General

1. Fire, smoke, combination fire/smoke and radiation dampers shall have the installation approved by the Authority Having Jurisdiction (AHJ) where field modifications are necessary as part of the manufacturer’s supplemental instructions.
2. Modifications must be made per the manufacturer’s installation instructions.
3. Some modifications fall under UL approval, some need AHJ approval.
4. Contact the manufacturer for guidance on modifications. The manufacturer will point out approved modifications and modifications needing AHJ approval. Manufacturers can also help explain the impact of modifications to the AHJ.
5. All dampers are recommended to be cycled after any modification.

6. UL Life Safety Damper actuators shall be factory installed and cycle-tested prior to shipment. Field mounting or substitutions of a damaged actuator is not covered under the UL certification and thus replacement shall be completed in accordance with the damper manufacturer’s field service program.

2.04 FIRE DAMPERS

A. Fire dampers shall be installed at all locations where ductwork or supply or return air openings penetrate any floor, wall or partition with a fire rating.

B. All fire dampers shall be of the “Dynamic” type as classified in UL Standard 555.

C. Fire dampers shall have a rating compatible with the floor, wall or partition, shall be tested to UL Standard 555 and be labeled for the intended installation (horizontal or vertical).

D. Fire Resistance Rating: 1½ hours unless noted otherwise indicated on drawings for 3 hours.

E. Closure device: Each fire damper shall be equipped with a factory installed heat responsive device (fusible link) rated to close the damper when temperature at the damper reaches: 165°F .

F. Airflow Closure Rating:

1. Dynamic fire dampers shall be selected for the velocity and pressure rating of the intended installation. Refer to the plans and schedules for airflow rates (CFM) and pressures (in. wg).
2. Dampers shall have a minimum velocity rating of 2000 fpm at a pressure rating of 4 in. wg.

3. Dampers in systems operating above 2000 fpm or 4 in. wg shall be selected for a velocity rating of 4000 fpm at a pressure rating of 6 in. wg.

G. Types:

1. Curtain: for use in systems up to 4000 fpm velocity; Style B or C with the blade stack out of the airstream (Style A with the blade stack in the airstream may be used behind registers and grilles or where space conditions do not permit the use of a Style B damper).
   a. Construction:
      1) Frame: Galvanized steel (in gauges required by manufacturer's UL listing).
      2) Blade design: interlocking galvanized steel
      3) Sleeves: Damper shall be supplied as a single assembly with a factory sleeve.
      4) Retaining Angles: Damper shall be supplied with factory retaining angles sized to provide installation overlap in accordance with the manufacturer's UL listing.
      5) Duct Transition Connection: breakaway type
      6) In corrosive and seacoast applications, damper assembly shall be constructed of Type 316 stainless-steel.
2. Round: for use in systems up to 2000 fpm velocity.
   a. Construction:
      1) Frame: Galvanized steel (in gauges required by manufacturer's UL listing).
      2) Blade design: single galvanized steel blade (in gauge required by manufacturer's UL listing).
      3) Retainer plate(s): supplied with damper.
      4) Sleeves: Length as required per wall thickness.
      5) Duct Transition Connection: breakaway type.
      6) In corrosive and seacoast applications, damper assembly shall be constructed of Type 316 stainless-steel.

H. All dampers shall be installed in strict accordance with the manufacturer's UL approved installation details.

I. Where fire dampers are required in a fibrous glass ductboard system, provide sheet metal sleeve per manufacturer's UL installation instructions. Verify gage of sleeve and attachment angle with governing code authorities. Installation shall also conform to SMACNA Figure 5-9 "Fibrous Glass Duct Installation".

2.05 CEILING RADIATION DAMPERS

A. A listed ceiling radiation damper shall be installed at all locations where ductwork or register, diffuser, grille, etc. penetrates the ceiling membrane of a fire-resistance-rated floor/ceiling or roof/ceiling assembly. Ceiling radiation dampers shall have a rating compatible with the floor/ceiling or roof/ceiling assembly and shall be tested to UL Standard 555C.

B. Fire Resistance Rating: 1 hour (minimum).

C. Closure device: Each ceiling radiation damper shall be equipped with a factory installed heat responsive device (fusible link) rated to close the damper when temperature at the damper reaches: 165°F

D. Construction:

1. Dampers shall be factory-built curtain or butterfly type. They shall conform to the requirements of NFPA Standard 90A and be UL Labeled for the required assembly rating.
2. All dampers shall be installed in strict accordance with the manufacturer's UL approved installation instructions.
3. Provide steel sleeves, mounting angles and steel duct drops of design and length where required to permit mounting within the opening.
4. Provide thermal blanket where required by the manufacturer's UL installation instructions.
5. Where ceiling radiation dampers are shown on the drawings, and if fiberglass ductwork is used, dampers shall be installed with a sheet metal collar or housing or shall be listed for use with fiberglass ductwork.

2.06 COMBINATION FIRE AND SMOKE DAMPERS

A. Fire/smoke dampers shall be installed at all locations where ductwork or supply or return air openings penetrate any floor, wall or partition with a fire and smoke rating, or where otherwise shown on the drawings.

B. Fire/smoke dampers shall be provided with actuators capable of closing the damper on activation of area smoke detectors, the fire alarm system and/or the Firefighter's Smoke Control Panel and shall be normally closed. Actuators shall be compatible with the activating smoke detectors or fire alarm system (coordinate with other trades).

C. Unless otherwise indicated, smoke detectors integral to the combination fire/smoke damper shall be furnished and installed by the fire alarm contractor (coordinate with other trades).

D. All combination fire/smoke dampers shall be of the "Dynamic" type as classified in UL Standards 555 and 555S.

E. Fire/smoke dampers shall have a rating compatible with the floor, wall or partition, shall be tested to UL Standards 555 and 555S and be labeled for the intended installation (horizontal or vertical).

F. Fire Resistance Rating: 1½ hours unless noted otherwise on drawings for 3 hours.

G. Leakage Rating: Class 1 (maximum of 8 cfm/ft^2 at 4 in. wg) unless noted otherwise.

H. Elevated Temperature Rating: 250°F (121°C) for 30 minutes. For smoke control systems provide provide dampers rated for 350°F (177°C) for 30 minutes.

I. Airflow Closure Rating:

1. Dynamic fire/smoke dampers shall be selected for the velocity and pressure rating of the intended installation. Refer to the plans and schedules for airflow rates (CFM) and pressures (in. wg).
2. Dampers shall have a minimum velocity rating of 2000 fpm at a pressure rating of 4 in. wg.

J. Types:

1. Round: for use in systems up to 3000 fpm velocity.
   a. Construction:
      1) Frame: Galvanized steel (in gauges required by manufacturer's UL listing).
      2) Blade design: single galvanized steel blade (in gauge required by manufacturer's UL listing).
      3) Retainer plate(s): supplied with damper.
      4) Sleeves: Length as required per wall thickness.
      5) Duct Transition Connection: breakaway type.
      6) In corrosive and seacoast applications, damper assembly shall be constructed of Type 316 stainless-steel.
2. Multi-blade:
   a. Up to 2000 fpm velocity: Triple Vee-groove type blade.
   b. 2000-4000 fpm velocity: Fabricated double skin airfoil type blade.
   c. Construction:
      1) Frame: Galvanized steel with mitered and interlocking corners (in gauges required by manufacturer's UL listing).
      2) Blade design: Galvanized steel (in gauges required by manufacturer's UL listing) strengthened by three longitudinal Vee grooves running the entire length of each blade as required by manufacturer's UL listing.
      3) Blade Stops: Each blade stop (at top and bottom of damper frame) shall occupy the minimum of the damper opening required by manufacturer's UL listing area to allow for maximum free area and to minimize pressure loss across the damper.
      4) Seals:
         a) Blade Edge: Blade seals shall be extruded silicone rubber permanently bonded to the appropriate blade edges.
         b) Jamb: Flexible stainless-steel compression type.
      5) Linkage: Concealed in jamb.
      6) Axles: Minimum ½" diameter plated steel.
      7) Bearings: Axle bearings shall be sintered bronze sleeve type or stainless steel rotating in polished extruded holes in the damper frame.
      8) Sleeves: Damper shall be supplied as a single assembly with a factory sleeve.
      9) Retaining Angles: Damper shall be supplied with factory retaining angles sized to provide installation overlap in accordance with the manufacturer's UL listing.

10) Duct Transition Connection: breakaway type
11) In corrosive and seacoast applications, damper assembly shall be constructed of Type 316 stainless-steel.

K. Heat Responsive Device: Electric, controlled closure, quick detect heat-actuated device designed to prevent damage to ductwork and other HVAC system components. The device shall be a reusable/resettable link (RRL) with a temperature setting of 165°F (74°C).

L. Photoelectric [ionization] Type Smoke Detector (if indicated on the drawings): rated for air velocities from 300 to 4000 fpm; UL268A listed, factory mounted internally on the damper sleeve

M. Damper Motors: Two-position meeting the following:

1. Comply with NEMA designation, temperature rating, service factor, enclosure type, efficiency requirements and the following:
   a. Motor Sizes: Minimum size as required by manufacturer's UL listing
   b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.
   c. 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°F (minus 40°C).
   d. Electrical Connection: 115 V, single phase, 60 Hz.

N. Momentary Test Switch (for use in combination fire and smoke dampers that are not part of a smoke management system): factory mounted and wired assembly for testing and cycling the damper during start-up and maintenance. Power wiring to test switch and actuator shall be per manufacturer's installation instructions.

O. Combination Fire and Smoke Dampers shall have a single point wiring per UL requirements (except where two signals are required as with the Temperature Limited Override specified above).

2.07 CORRIDOR COMBINATION FIRE AND SMOKE DAMPERS

A. Corridor fire/smoke dampers shall be installed at all locations where ductwork or supply or return air openings penetrate any tunnel corridor ceiling with a fire and smoke rating, or where otherwise shown on the drawings.

B. Corridor fire/smoke dampers shall be provided with actuators capable of closing the damper on activation of area smoke detectors, the fire alarm system and/or the Firefighter's Smoke Control Panel and shall be normally closed. Actuators shall be compatible with the activating smoke detectors or fire alarm system (coordinate with other trades).

C. Unless otherwise indicated, smoke detectors integral to the corridor fire/smoke damper shall be furnished and installed by the fire alarm contractor (coordinate with other trades).

D. All corridor fire/smoke dampers shall be of the "Dynamic" type as classified in UL Standards 555 and 555S.

E. Corridor fire/smoke dampers shall be tested to UL Standards 555 and 555S and be labeled for the intended installation.

F. Maximum pressure drop: 0.10 in. wg; provide ductwork transitions as required so as not to exceed maximum pressure drop.

G. Fire Resistance Rating: 1 hour.

H. Leakage Rating: Class 1 (maximum of 8 cfm/ft^2 at 4 in. wg) unless noted otherwise.

I. Elevated Temperature Rating: 250°F (121°C) for 30 minutes. For smoke control systems provide provide dampers rated for 350°F (177°C) for 30 minutes.

J. Airflow Closure Rating:

1. Dynamic fire/smoke dampers shall be selected for the velocity and pressure rating of the intended installation. Refer to the plans and schedules for airflow rates (CFM) and pressures (in. wg).
2. Dampers shall have a minimum velocity rating of 2000 fpm at a pressure rating of 4 in. wg.

K. Types:

1. Round: for use in systems up to 3000 fpm velocity.
   a. Construction:
      1) Frame: Galvanized steel (in gauges required by manufacturer's UL listing).
      2) Blade design: single galvanized steel blade (in gauge required by manufacturer's UL listing).
      3) Retainer plate(s): supplied with damper.
      4) Sleeves: Length as required per wall thickness.
      5) Duct Transition Connection: breakaway type.
      6) In corrosive and seacoast applications, damper assembly shall be constructed of Type 316 stainless-steel.
2. Multi-blade:
   a. Up to 2000 fpm velocity: Triple vee-groove type blade.
   b. 2000-4000 fpm velocity: Fabricated double skin airfoil type blade.
   c. Construction:
      1) Frame: Galvanized steel with mitered and interlocking corners (in gauges required by manufacturer's UL listing).
      2) Blade design: 16 ga. galvanized steel strengthened by three longitudinal 1" deep Vee grooves running the entire length of each blade. Each blade shall be symmetrical relative to its axle pivot point, presenting identical performance characteristics with air flowing in either direction through the damper. Provide symmetrical blades of varying size as required to completely fill the damper opening.

3) Blade Stops: Each blade stop (at top and bottom of damper frame) shall occupy no more than ½" of the damper opening area to allow for maximum free area and to minimize pressure loss across the damper.
4) Seals:
   a) Blade Edge: Blade seals shall be extruded silicone rubber permanently bonded to the appropriate blade edges.
   b) Jamb: Flexible stainless-steel compression type.
5) Linkage: Concealed in jamb.
6) Axles: Minimum ½" diameter plated steel.
7) Bearings: Axle bearings shall be sintered bronze sleeve type rotating in polished extruded holes in the damper frame.
8) Sleeves: Damper shall be supplied as a single assembly with a factory sleeve.
9) Retaining Angles: Damper shall be supplied with factory retaining angles sized to provide installation overlap in accordance with the manufacturer's UL listing.
10) Duct Transition Connection: breakaway type
11) In corrosive and seacoast applications, damper assembly shall be constructed of Type 316 stainless-steel.

L. Heat Responsive Device: Electric, controlled closure, quick detect heat-actuated device designed to prevent damage to ductwork and other HVAC system components. The device shall be a reusable/resettable link (RRL) with a temperature setting of 165°F (74°C).

M. Photoelectric [ionization] Type Smoke Detector (if indicated on the drawings): rated for air velocities from 300 to 4000 fpm; UL268A listed, factory mounted internally on the damper sleeve.

N. Damper Motors: Two-position meeting the following:

1. Comply with NEMA designation, temperature rating, service factor, enclosure type, efficiency requirements and the following:
   a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so the driven load will not require motor to operate in service factor range above 1.0.
   b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.
   c. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
   d. 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).
   e. 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°F (minus 40°C).

f. 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).

g. Electrical Connection: 115 V, single phase, 60 Hz.

2. Momentary Test Switch (for use in combination fire and smoke dampers that are not part of a smoke management system): factory mounted and wired assembly for testing and cycling the damper during start-up and maintenance. Power wiring to test switch and actuator shall be per manufacturer's installation instructions.

O. Corridor Combination Fire and Smoke Dampers shall have a single point wiring per UL requirements (except where two signals are required as with the Temperature Limited Override specified above).

2.08 SMOKE DAMPERS

A. Smoke dampers shall be installed at all locations where ductwork or supply or return air openings penetrate any floor, wall or partition with a smoke rating, or where otherwise shown on the drawings, except where such ductwork or openings are part of an engineered smoke removal system.

B. Smoke dampers shall be provided with factory installed actuators capable of closing the damper on activation of area smoke detectors, the fire alarm system and/or the Firefighter's Smoke Control Panel and shall be normally closed. Actuators shall be compatible with the activating smoke detectors or fire alarm system (coordinate with other trades).

1. For stair and elevator hoist-way pressurization fans, provide a Class 1, normally open smoke damper at the fan inlet for use as a control damper; Ruskin Model SD60, Pottorff Model SD-151, or equal.

C. Unless otherwise indicated, smoke detectors integral to the smoke damper shall be furnished and installed by the fire alarm contractor (coordinate with other trades).

D. All smoke dampers shall be tested and certified in accordance with UL Standard 555S.

E. Leakage Rating: Class 1 (maximum of 8 cfm/ft^2 at 4 in. wg) unless noted otherwise.

F. Elevated Temperature Rating: 350°F (177°C) for 30 minutes.

G. Airflow Closure Rating:

1. Dynamic smoke dampers shall be selected for the velocity and pressure rating of the intended installation. Refer to the plans and schedules for airflow rates (CFM) and pressures (in. wg).
2. Dampers shall have a minimum velocity rating of 2000 fpm at a pressure rating of 4 in. wg.
3. Dampers in systems operating above 2000 fpm or 4 in. wg shall be selected for a velocity rating of 4000 fpm at a pressure rating of 6 in. wg.

H. Types:

1. Round: for use in systems up to 3000 fpm velocity.
   a. Construction:
      1) Frame: Galvanized steel (in gauges required by manufacturer's UL listing).
      2) Blade design: single double skin galvanized steel blade (in gauge required by manufacturer's UL listing).
      3) Retainer plate(s): supplied with damper.
      4) Sleeves: Length as required per wall thickness.
      5) Duct Transition Connection: breakaway type.
      6) In corrosive and seacoast applications, damper assembly shall be constructed of Type 316 stainless-steel.
2. Multi-blade:
   a. Up to 2000 fpm velocity: Triple Vee-groove type blade.
   b. 2000-4000 fpm velocity: Fabricated double skin airfoil type blade.
   c. Construction:
      1) Frame: Galvanized steel with mitered and interlocking corners (in gauges required by manufacturer's UL listing).
      2) Blade design: Galvanized steel strengthened longitudinal Vee grooves running the entire length of each blade.
      3) Blade Stops: Each blade stop (at top and bottom of damper frame) shall occupy the minimum damper opening area required by manufacturer's UL listing to allow for maximum free area and to minimize pressure loss across the damper.
      4) Seals:
         a) Blade Edge: Blade seals shall be extruded silicone rubber permanently bonded to the appropriate blade edges.
         b) Jamb: Flexible stainless-steel compression type.
      5) Linkage: Concealed in jamb.
      6) Axles: Minimum ½" diameter plated steel.
      7) Bearings: Axle bearings shall be sintered bronze sleeve type or stainless steel rotating in polished extruded holes in the damper frame.
      8) Sleeves: Damper shall be supplied as a single assembly with a factory sleeve.
      9) Retaining Angles: Damper shall be supplied with factory retaining angles sized to provide installation overlap in accordance with the manufacturer's UL listing where required.
      10) Duct Transition Connection: breakaway type
      11) In corrosive and seacoast applications, damper assembly shall be constructed of Type 316 stainless-steel.

I. Photoelectric [ionization] Type Smoke Detector (if indicated on the drawings): rated for air velocities from 300 to 4000 fpm; UL268A listed, factory mounted internally on the damper sleeve.

J. Damper Motors: Two-position meeting the following:

1. Comply with NEMA designation, temperature rating, service factor, enclosure type, efficiency requirements and the following:
   a. Motor Sizes: Minimum size as required by manufacturer's UL listing.
   b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.
   c. 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°F (minus 40°C).
   d. Electrical Connection: 115 V, single phase, 60 Hz.
2. Momentary Test Switch (for use in smoke dampers that are not part of a smoke management system): factory mounted and wired assembly for testing and cycling the damper during start-up and maintenance. Power wiring to test switch and actuator shall be per manufacturer's installation instructions.

K. Accessories for active smoke management systems:

1. Open Closed Indicator (OCI): factory mounted and tested with two switches, one set to close when the damper blades are at their open position, and the other set to close when the damper blades are at their closed position. This will be wired to the Fire Fighter's Smoke Control Station to indicate true damper position.
2. Test Switch and Indicator Panel: 5" x 5" control panel with toggle switch, red LED (replaceable) indicator light to indicate closed damper position and a green LED (replaceable) indicator light to indicate open damper position.
3. Power wiring to OCI, test switch and actuator shall be per manufacturer's installation instructions.

L. Smoke Dampers shall have a single point wiring per UL requirements.

2.09 CONTROL DAMPERS

A. Automatic control dampers shall be installed as shown on the drawings and shall be controlled as described in the 23 09 00 - Automatic Controls section of these specifications.

B. Unless indicated otherwise, dampers shall be of the opposed blade type constructed of minimum 18-gauge galvanized steel and shall have rigidly constructed blades less than 6" wide and shall have duct mounting flanges.

C. Dampers shall be the low leakage type with replaceable blade and jamb seals. Maximum pressure drop for dampers operating in systems exceeding 2000 fpm shall be 0.10 in. wg.

D. Outside air supply and exhaust openings shall be provided with a Class 1 motorized damper with a maximum leakage rate of 4 cfm/ft^2 (20.3 L/s · m^2) at 1.0 in. wg (249 Pa) when tested in accordance with AMCA 500D.

1. Gravity (non-motorized) dampers having a maximum leakage rate of 20 cfm/ft^2 (101.6 L/s · m^2) at 1.0 in. wg (249 Pa) when tested in accordance with AMCA 500D may be used in any one of the following conditions:
   a. In buildings for exhaust and relief dampers.
   b. In buildings of less than three stories in height above grade.

c. For ventilation air intakes and exhaust and relief dampers in buildings of any height in Climate Zones 1, 2 and 3.
d. Where the design outdoor air intake or exhaust capacity does not exceed 300 cfm (141 L/s).

Gravity (non-motorized) dampers for ventilation air intakes shall be protected from direct exposure to wind.

2. Dampers smaller than 24 inches (610 mm) in either dimension shall be permitted to have a leakage rate of 40 cfm/ft2 (203.2 L/s · m2) at 1.0 in. wg (249 Pa) when tested in accordance with AMCA 500D.

2.10 CONSTANT AIRFLOW REGULATORS

A. Type: Project shall use a modulating passive pressure independent control orifice that automatically regulates supply, return or exhaust airflows in duct systems to constant levels. The orifice shall respond to duct pressure without the use of electric or pneumatic controls or sensors. The product shall be available for new construction or retrofit applications and eliminates the need for on-site testing, adjusting and balancing (TAB).

B. Quality Assurance:

1. Regulators shall be listed under UL 2043 – Standard for Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces
2. Ceiling radiation dampers provided from the factory shall be listed under UL 555C – Standard for Ceiling Dampers and Ceiling Air Diffusers
3. Manufacturer shall have been engaged in the production of this type of equipment for a minimum of ten (10) years.

C. Construction:

1. Frame and Blade shall be made of ABS plastic meeting the requirements of UL 94 V-0 flammability standard.
2. Damper: Aero-wing (aerofoil type)
3. Outer Seal: Flex-type ring seal gasket
4. Temperature range: -25°F to 140°F
5. Static pressure operating range: Low Pressure from 0.10 to 0.42 in. wg, Standard Pressure from 0.2 to 0.8 in. wg, High Pressure from 0.6 to 2.4 in. wg.
6. Airflow adjustment: Factory calibrated. Contact the manufacturer for any field adjustments.

D. Available accessories:

1. Quick-connect rings for square ducts
2. Rectangular to round adapters
3. Grille mount box
4. Fire damper
5. Boot with ceiling radiation damper (UL 555C listed for floor/ceiling or roof/ceiling 3-hour fire resistance assemblies)

E. Available sizes: 4", 5", 6", 8", and 10"

F. Manufacturer Basis of Design: American Aldes Model CAR

G. Warranty: Five (5) years from date of shipment
H. Equal products by: Greenheck, Pottorff

2.11 REMOTE DAMPER OPERATORS

A. Cable operated type:

1. Manufacturers: Subject to compliance with all requirements: Pottorff, Ventfabrics, Inc., Duro Dyne or Young Regulator Company.
2. Description: Cable system designed for remote manual damper adjustment.
3. Cable: Stainless steel with flexible steel casing or steel with synthetic casing.
4. Control: Concealed regulator kit with steel locking rack and pinion gear with hex head adjustment or damper control is via push-pull lever action.
5. Linear slot diffuser: Pottorff Models RCS-10 (rectangular) or RCS-10R (round) or Young Regulator Model 270-275ML plenum mounted cable controller with 5020CC (round) or 830AC (rectangular) balancing damper.

B. Install in strict conformance with manufacturer's installation instructions.

2.12 FLEXIBLE DUCT CONNECTORS

A. Install flexible duct connectors at connections of sheet metal duct to motor driven equipment, in ductwork crossing building expansion joints, or otherwise noted. Install per manufacturer's instructions, and support sheet metal ductwork so that no weight is supported by the flexible duct connector.

B. Basis-of-Design Product unless noted otherwise below: Subject to compliance with requirements, provide Ductmate Industries, Inc.; PROflex or comparable product by one of the following:
1. Duro Dyne Inc.
2. Ventfabrics, Inc
3. Prior Approved Equal

C. Materials: Flame-retardant or noncombustible fabrics compliant with NFPA 701.

D. Coatings and Adhesives: Comply with UL 181, Class 1 and have a maximum flame spread/smoke developed rating of 25/50.

E. Metal-Edged Connectors: Factory fabricated with a fabric strip 5¾-inches wide attached to two strips of 2¾-inch wide, 0.028-inch thick, galvanized sheet steel. Provide metal compatible with connected ducts.

F. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 26 oz./sq. yd.

2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
3. Service Temperature: Minus 40 to plus 200ºF.

G. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone.

1. Minimum Weight: 24 oz./sq. yd.
2. Tensile Strength: 530 lbf/inch in the warp and 440 lbf/inch in the filling.
3. Service Temperature: Minus 50 to plus 250ºF.

H. 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 ¼-inch movement at start and stop.

I. For systems operating at +4 in. wg, provide a molded rubber duct expansion joint. Construction shall consist of an elastomer tube and cover, reinforced with a woven fabric capable of accommodating duct system movement and vibration. Expansion joints shall be Flexicraft Industries, Rubber Duct Expansion Joint Model.

2.13 ACCESS DOORS

A. Hinged, gasketed and latched Access Doors (AD) and/or panels shall be installed at each fire and smoke damper, each duct mounted smoke detector, each valve, at each duct mounted balancing damper or any other mechanical equipment or device that requires accessibility. Doors and panels shall be sized (minimum 18" x 18", duct size allowing), and located to optimize access to dampers, detectors, and other equipment for service and replacement. Access Panels (AP) in walls, ceilings or other surfaces shall be coordinated with architectural finishes and selected by the architect.

B. Access doors shall be designed for five times the pressure of the duct in which it is mounted.

C. Access doors for fire dampers, combination fire/smoke dampers and smoke dampers in medium pressure (+4 in.wg and higher) duct systems shall be the implosion type designed to prevent excessive negative pressure downstream resulting in collapsed ductwork. At the contractor’s option, the access door may be an integral feature of the damper assembly.

D. Access doors for grease exhaust ducts shall be in accordance with NFPA 96 (latest edition). Vertical grease ducts shall have an access door at each floor level in an inconspicuous location.

E. Access doors for fire dampers, combination fire/smoke dampers and smoke dampers shall be permanently identified by a die-cut label with ½" high red block letters on a white background. Label shall read FIRE DAMPER, COMBINATION FIRE/SMOKE DAMPER or SMOKE DAMPER.

F. Duct-Mounted Access Doors: Fabricate access panels per SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 7-2 (7-2M), "Duct Access Doors and Panels," and 7-3, "Access Doors - Round Duct".

1. Basis-of-Design Product: Subject to compliance with requirements, provide Ductmate Industries, Inc.; Access Doors or comparable product by one of the following:
   a. American Warming and Ventilating; a division of Mestek, Inc.
   b. Ward Industries, Inc.; a division of Hart & Cooley, Inc.
   c. Prior Approved Equal
2. Door:
   a. Double wall, rectangular.
   b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
   c. Vision Panel:
      1) Observation type doors shall be sandwich type provided at all fire and smoke dampers, humidifiers, in-duct smoke detectors, and UVC emitters.
      2) Minimum 12"x12" with 8"x8" viewport, insulated or non-insulated.
      3) For ducts smaller than 12-inches, 10"x6" shall be used with a 4"x 2-5/8" viewport with a single pane of safety glass.
   d. Hinges and Latches: 1"x1" butt or piano hinge with cam latches.
   e. Fabricate doors airtight and suitable for duct pressure class.
3. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
4. Number of Hinges and Locks:
   a. Access Doors Less Than 12 inches Square: No hinges and two sash locks.
   b. Access Doors up to 18 inches Square: Continuous hinge and two sash locks.
   c. Access Doors up to 24 by 48 inches: Continuous hinge and two compression latches.
   d. Access Doors Larger Than 24 by 48 inches: Continuous hinge and two compression latches.

G. Pressure Relief Access Door:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. American Warming and Ventilating; a division of Mestek, Inc.

b. Cesco Products; a division of Mestek, Inc.
c. Elgen Manufacturing
d. Flexmaster U.S.A., Inc.
e. Greenheck Fan Corporation
f. McGill AirFlow LLC
g. Nailor Industries Inc.
h. Pottorf
i. Ventfabrics, Inc.
j. Ward Industries, Inc.; a division of Hart & Cooley, Inc.
k. Prior Approved Equal

2. Door and Frame Material: Galvanized sheet steel.
3. Door: Single or Double wall with insulation fill, as required, with metal thickness applicable for duct pressure class.
4. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.
5. Factory set at 3.0- to 8.0-in. wg.
6. Doors close when pressures are within set-point range.
7. Hinge: Continuous piano
8. Latches: Cam
9. Seal: Neoprene or foam rubber
10. Insulation Fill: 1" thick, fibrous-glass or polystyrene-foam board.

H. Duct Access Panel Assemblies:

1. Basis-of-Design Product: Subject to compliance with requirements, provide Ductmate Industries, Inc.; Ultimate Door or comparable product by one of the following:
   a. Flame Gard, Inc.
   b. Prior Approved Equal
2. UL 1978 listed by an NRTL
3. Panel and Frame: Minimum thickness 0.0528-inch carbon steel.
4. Fasteners: Carbon steel. Panel fasteners shall not penetrate duct wall.
5. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000ºF.
6. Minimum Pressure Rating: 10-inch wg, positive or negative.

2.14 DUCT LINER

A. Also refer to Section 23 07 00 - HVAC Insulation.

B. Supply air ductwork a minimum of 15 linear feet downstream and return air ductwork a minimum of 15 linear feet upstream of low-pressure air handling equipment and terminal units shall be internally lined with 1½" thick acoustical duct liner/insulation (minimum R-6 or greater where required by code), Johns Manville Linacoustic RC or approved equal.

1. Duct liner shall be securely fastened to ductwork with stick pins, speed washers and adhesive.
2. Leading edges of liner shall have a sheet metal nosing.

3. Exposed edges and butt joints shall be “buttered” with duct sealer.
4. Duct liner shall be interrupted at all fire, smoke, combination fire/smoke and radiation dampers.
5. Duct liner shall be interrupted not less than 6" upstream and 6" downstream of electric-resistance and fuel-burning heaters in a duct system.

C. Supply air ductwork a minimum of 50 linear feet (or as indicated) downstream of static pressure class +4 in. wg air handling equipment shall be internally lined with 1½" thick acoustical duct liner/insulation, (minimum R-6 or greater where required by code) Johns Manville Linacoustic RC or approved equal. Return air ductwork shall be lined as described in 2.13.B above or as indicated.

D. Return air ductwork, sound boots and transfer ducts shall have 1" thick liner, Johns Manville Linacoustic RC or approved equal.

1. Refer to Section 23 07 00 - HVAC INSULATION for return air ductwork requiring external insulation.

E. Indoor exposed rectangular sheet metal supply and return air ductwork shall be lined with 1" thick duct liner (minimum R-4 or greater where required by code) Johns Manville Linacoustic RC or equal.

F. Indoor exposed round, spiral or flat oval ductwork shall be lined with 1" thick fiberglass duct liner/insulation (minimum R-4 or greater where required by code) Johns Manville Spiracoustic Plus or approved equal.

G. Subject to compliance with requirements, duct liner products shall be manufactured by: CertainTeed, Johns Manville, Knauf, Owens Corning, or approved equal.

PART 3 – EXECUTION

3.01 INSTALLATION

A. All ductwork shall be installed in accordance with applicable SMACNA Standards according to the pressure class described in PART 1 - GENERAL.

B. Seal, inspect and test ductwork prior to insulating or concealing. Seal all ductwork and plenums to meet the following SMACNA duct seal class:

1. Class A: Seal all transverse joint, longitudinal seams, and duct wall penetrations.
   a. Pressure-sensitive tape shall not be used as the primary sealant, unless it has been certified to comply with UL 181A or UL 181B by an independent testing laboratory and the tape is used in accordance with that certification.
   b. All connections shall be sealed, including but not limited to spin-in fittings, taps, other branch connections, access doors, and duct connections to equipment.
   c. Sealing that would void product listings is not required.
   d. Spiral lock seams need not be sealed.

2. Tapes, sealants and mastics used to seal metallic and flexible air ducts and flexible air connectors shall comply with UL 181B and shall be marked "181B-FX" for pressure-sensitive tape or "181B-M" for mastic/sealant.
3. Mechanical fasteners for use with flexible nonmetallic air ducts shall comply with UL 181B and shall be marked "181B-C".

C. Seal the annular space around all duct, grilles, registers, diffusers, etc. penetrations through walls, floors, and ceilings airtight with an approved material. Refer to the Architectural documents for approved materials.

D. Sheet metal and flexible ductwork shall be supported as recommended by SMACNA Standards from structural members. Zip ties are not an acceptable method for suspending ductwork. Ductwork shall not be allowed to rest on ceilings, light fixtures or structural members. Ductwork supported from joists shall be supported from the top chord of all joists.

E. All ductwork accessories shall be installed in strict accordance with manufacturer's recommendations.

F. Ductwork that is designed to operate at static pressures in excess of 3 in. wg and all ductwork located outdoors shall be leak-tested in accordance with SMACNA Standards. Representative sections totaling no less than 25% of the total installed duct area for the designated pressure class shall be tested. All sections shall be selected by the building owner or the designated representative of the building owner. Positive pressure leakage testing is acceptable for negative pressure ductwork. The maximum permitted duct leakage shall be:

$$L_{max} = C_L P^{0.65}$$

where

L_{max} = maximum permitted leakage, cfm per100 ft^2 of duct surface area
C_L = 4, duct leakage class, cfm per100 ft^2 of duct surface area per inch of $water^{0.65}$
P = test pressure, which shall be equal to the design duct pressure class rating, in. of water

All ductwork seams shall be sealed with mastic to provide a system that is within the recommended SMACNA leakage limits. As an alternate, water-based spray-on hardcast products may be used provided they meet or exceed the project requirements.

The ductwork test report shall be submitted in electronic (PDF) format to the Engineer prior to the Contractor's request for final payment.

G. All ductwork shall be cleaned inside and out prior to system start up and shall be left in a neat and orderly manner.

H. Duct sizes shown on drawings are inside clear dimensions.

I. Unless otherwise approved, ducts shall be true to dimensions indicated, straight and smooth on the inside with neatly finished joints, securely anchored to the building in an approved manner, and installed to be completely free from vibration under all conditions of

operation. Exact routing of ductwork will be dependent on location of framing members. Route ductwork to avoid cutting framing members.

J. Brace ducts not more than 60 inches on center.

K. Make slip joints in the direction of air flow.

L. Offset ducts around obstructions where possible. Where duct must encompass obstruction, area of duct shall remain constant.

M. Duct tapers shall not exceed 1:4 ratio and transformations 30 degrees between air flow and diverging or converging air flow.

N. Provide access doors for access to all equipment, dampers and motors concealed by sheet metal.

O. Where applicable, provide seismic bracing and restraints for ductwork per ASCE/SEI 7, latest edition and the latest edition of the SMACNA Seismic Restraint Manual. Also, refer to Section 23 05 48 Noise and Vibration Control.

3.02 BALANCING DAMPERS

A. Install manual volume dampers where indicated on the drawings and where required to properly balance the air distribution system.

B. Provide an opposed blade damper behind the face of each supply register which shall be adjustable through the face of the register with a screwdriver.

C. Provide an opposed blade damper behind the face of return air registers, where indicated, which shall be adjustable through the face of the register with a screwdriver.

D. Provide a butterfly damper in the neck of each ceiling diffuser unless noted otherwise.

END OF SECTION

SECTION 23 34 00 - UNITARY EXHAUST AND SUPPLY FANS AND VENTILATORS

PART 1 - GENERAL

1.01 DESCRIPTION

A. Refer to specification section 23 00 00 - HVAC General, all of which applies to work described in this section as if written in full herein. Special attention should be given to Section 2.02 ELECTRICAL WORK for specifics on motor and drive requirements.

B. Furnish and install all unitary exhaust and supply fans and ventilators of the size, type, capacity and characteristics as shown on the equipment schedules and herein described.

C. Base fan-performance ratings on actual project site altitude.

D. Acceptable manufacturers include only those whose products have been in satisfactory use in similar service for not less than five (5) years.

E. Electrical Standards: Provide electrical motors and products which have been listed and labeled by Underwriters Laboratories Inc. and comply with NEMA Standards.

F. Certification, Fan Performance: Fans shall be certified to bear the AMCA label for air and sound performance.

PART 2 - PRODUCTS

2.01 CENTRIFUGAL AND AXIAL FANS AND VENTILATORS

A. All units shall be rigidly constructed of materials suitable for the intended service and shall be installed with all accessories listed on the Drawings.

B. All roof mounted units shall be installed on factory supplied 14-inch high (minimum) insulated roof curbs of the proper type, size and construction for proper mounting. Curbs shall account for all roof slopes and pitches so that the unit is installed level. Units shall be anchored to curbs by a minimum of two lag screws of adequate size on each side. Curbs shall be constructed of galvanized steel, except when the project is located within 5 miles of a sea coast they shall be of aluminum construction.

C. Outdoor fans shall be completely weatherproof for outdoor installation and shall contain internal vibration isolation to assure smooth and quiet performance.

D. Fan wheels and blades shall be constructed of aluminum and shall be statically and dynamically balanced at the factory.

2.02 CEILING-CENTRIFUGAL AND CABINET FANS

A. Units shall be direct-drive type with back-draft damper, acoustically insulated cabinets and speed controller.

2.03 EXHAUST FANS SERVING KITCHEN HOODS

A. Grease handling exhaust fans shall carry a UL 762 Listing and shall be provided with all accessories/features required to meet that listing.

B. Grease exhaust fans shall discharge a minimum of 42" above the finished roof.

2.04 EXHAUST FANS SERVING DISHWASHERS

A. Dishwasher exhaust fans shall be all aluminum construction.

PART 3 - EXECUTION

3.01 GENERAL

A. All units shall be installed in accordance with manufacturer’s recommendations and as shown on the Drawings.

B. Ceiling-centrifugal and cabinet fans shall be supported from structural members and shall not rest on the ceiling, on lights or on structural members.

C. Units shall be interlocked and controlled as indicated on the Drawings.

D. Ceiling-mounted units shall be installed with ceiling grilles flush with the ceiling.

E. Curb-mounted fans shall be secured to the roof curb with lag screws in each hole in the fan curb cap.

F. Electrical connection to the fan motor shall be made through the roof opening inside the roof curb.

G. Replace fan and motor pulleys as required to achieve design airflow.

END OF SECTION

SECTION 23 37 00 - LOUVERS, GRILLES, REGISTERS AND DIFFUSERS

PART 1 - GENERAL

1.01 DESCRIPTION

A. All work in this section shall be subject to the provisions of Section 23 00 00 - HVAC General.

B. Furnish and install all louvers, grilles, registers and diffusers of the size, type, capacity, and characteristics as shown on the equipment schedules and specified herein.

C. Equipment schedules and specifications are intended to establish a minimum level of quality and workmanship for the project. When other than the basis of design equipment is proposed, the Contractor shall be responsible for all costs associated with engineering and construction modifications necessary in his or any other trade that may be required to satisfy the Contract Documents.

D. Refer to the drawings for basis of design manufacturer and acceptable alternates.

PART 2 - PRODUCTS

2.01 LOUVERS

A. Louver components (heads, jambs, sills, blades, etc.) shall be factory assembled by the manufacturer into a complete unit. Louver sizes too large for shipping shall be built-up from factory assembled louver sections to provide the overall sizes required.

B. Louver design shall incorporate structural supports required to withstand a wind load of 20 lbs./square foot.

C. All louver performance data submitted for approval shall bear the AMCA Certified Ratings Seal for Air Performance and Water Penetration.

D. All louvers shall have a factory applied finish coating as scheduled with the color selection made by the Architect at the time of shop drawing approval. Color charts shall be submitted with louver shop drawings.

E. Screens:

1. General: Provide a screen at each exterior louver.
2. Frames: Same kind and form of metal as indicated for louver to which screens are attached.
3. Screening material:
   a. Bird Screen: Aluminum, ¼" by ¼" square mesh wire; 0.047" thick

2.02 SEVERE DUTY LOUVERS

A. In hurricane prone regions (as defined by the International Building Code) and where scheduled, louvers shall be the severe duty type to protect intake and exhaust openings from wind-driven rain and wind-borne debris.

B. Severe duty louvers shall be AMCA certified in accordance with AMCA 540/550, Enhanced Level E, for water, air and wind-driven rain.

C. Structural Performance: Severe duty louvers shall withstand the effects of gravity loads, wind loads and stresses within limits and under conditions indicated without permanent deformation of louver components, noise or metal fatigue caused by louver blade rattle or flutter, or permanent damage to fasteners and anchors.

1. Wind-Load: 150 lbs./sq. ft. (7.182 kPa) maximum pressure acting inward or outward

D. Florida Product Approved louvers are acceptable for use in Florida's High Velocity Hurricane Zone if a Miami-Dade Notice of Acceptance in not required.

2.03 GRILLES, REGISTERS AND DIFFUSERS

A. Units shall be of the type, size, and construction as scheduled or indicated.
B. Unless otherwise noted or indicated, all air devices shall be supplied with a factory finish of manufacturer's standard white.

C. Grilles, registers and diffusers shall be ordered with borders compatible with the ceiling system type in which they are installed. Refer to architectural drawings for type of ceiling and/or suspension system.

D. Aluminum air devices shall be used for all areas subject to excessive moisture or humidity (e.g. showers, pools, bathrooms, etc.).

PART 3 - EXECUTION

3.01 LOUVERS

A. Louvers shall be installed in accordance with the manufacturer's recommendations.

B. The louver installation shall be made weatherproof by caulking and sealing at the frame and flanges in accordance with the manufacturer's recommendations.

C. Combination louver/dampers shall be installed with the required actuators and linkage mechanisms and shall be field adjusted for full opening/closure stroke. Louvers shall be interlocked as scheduled or indicated.

3.02 GRILLES, REGISTERS AND DIFFUSERS

A. All air devices located in ceiling tiles shall be centered or shall be on quarter points of 2 ft. x 2 ft. tiles.

B. Where a line of sight allows the ductwork, wall, or ceiling structure to be seen behind any units, such ductwork, wall or ceiling structure shall be painted with nonflammable flat black paint to minimize visibility.

C. All air devices not installed on T-bar ceiling grids shall be securely fastened to adjacent structures.

D. Where air distribution devices are installed in inaccessible ceilings, provide the spin-in fitting without a volume damper. Provide an opposed blade damper in the neck of the air distribution device with access to the damper control through or at the face of the device.

END OF SECTION

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SECTION 23 38 00 - KITCHEN VENTILATION EQUIPMENT

PART 1 - GENERAL

1.01 DESCRIPTION

A. Furnish and install a self-compensating ventilation canopy over the cooking battery complete with makeup and exhaust fans with curbs, grease filters, dry chemical fire suppression system, vapor-proof lights and controls.

PART 2 - PRODUCTS

2.01 KITCHEN HOOD VENTILATION AND EXHAUST SYSTEM

A. Description: Hood over food cooking equipment shall provide for both air supply and air exhaust. Supply air provided through blower with filters directly from outside. Exhaust air pulled through “grease” extractor filters and discharged vertically above the roof. Canopy shall be constructed with a totally welded inner exhaust canopy and a complete outer canopy providing an air plenum between the exhaust and supply canopies on the top and front. Canopy ends shall be double thickness 18-gauge material as specified. Canopy shall be of the short circuit design. Refer to the Drawings for model, size and capacities.

B. Features of Range Hood:

1. Stainless steel construction with matching soffit above to ceiling. Outside surface shall be finished white epoxy enamel.
2. “Grease” extractor filters shall be stainless steel, UL Labeled, 20" x 20" x 2" size, self-draining.
3. Removable grease gutters under filters, pitched to drain to a removable metal collection container.
4. Makeup air slots shall be adjustable. Hood shall have been tested and rated by Underwriters Laboratories Inc. for a proven exhaust rate of 250 cfm L/F over high heat (600 degrees F+) cooking equipment with a supply air ratio of 84%, as listed by UL for the high heat test.
5. Built in vapor proof hood interior lights, one per each 3 feet of length, pre-wired to switch.
6. Pre-wired control panels with stainless steel exposed surface containing operating pilot lights and switches.
7. Hood size to completely cover the cooking equipment plus an overhang of 12" minimum on all sides.
8. Hood to be UL classified.

C. Features of Duct Package:

1. Exhaust duct shall be all welded construction per NFPA 96.
2. Exhaust and supply ducts shall be of the concentric arrangement and UL Labeled number MH10644 so that the exterior duct can be installed to within 1" of

combustible materials. Duct to include slip joint connections as approved by UL for vertical duct, with horizontal duct to include flanges for field welding.

3. Parallel duct arrangement is acceptable providing the Contractor satisfies the clearance requirements of NFPA 96 and the local fire marshal.

D. Features of Roof-Mounted Assembly:

1. Supply air fan package constructed of aluminized steel including intake section with air filters and birdscreen, support legs and factory enamel finish.
2. Top discharge exhaust fan with plug in connection for master electric panel, furnished for field installation of factory furnished economizer section. No birdscreens or backdraft dampers. The fan shall be UL Labeled for grease contaminated air. Provide low silhouette curb as drawn.
3. Master electric pre-wired control panel, factory mounted and wired with main power source connection, control circuit terminal strip, magnetic motor contactors, manual motor overload switch, contactors, relays, transformers, circuit breakers, fuses and fused disconnect.
4. Factory wiring in conduit conforming to NFPA Standard 70 and designed to withstand effects of heat, vapor and grease on the equipment. Wiring shall include low voltage (24 volt) control wiring in conduit to opening in top of canopy, connecting wiring harness and conduit to master electric control panel.
5. A complete kitchen hood fire extinguishing system shall be provided under this item.
6. Approval: The “Seal of Approval” of the NATIONAL SANITATION FOUNDATION TESTING LABORATORY (NFS) shall appear on the Ventilation System.
7. Code: The system construction shall be in accordance with NFPA Standard 96, “Vapor Removal from Commercial Cooking Equipment,” and the Southern Building Code Congress.
8. Manufacturers: Duo-Aire, Greenheck, Cambridge-XL.

2.02 EXHAUST CANOPY FIRE PROTECTION SYSTEM

A. The fire suppression protection system should be of the stored pressure, wet chemical pre-engineered fixed nozzle type manufactured by Wells Fargo Pyro Technologies, Inc. A carbon dioxide cartridge is designed in compliance with Military Specification “MIL-C-601G,” and shall be used as the pneumatic releasing device for the system. The cartridge shall be an integral part of the control head assembly. The wet chemical storage cylinder shall be D.O.T. rated for stored pressure of 175 psig, and a pressure gauge shall be provided on the cylinder valve for visual inspection. The system shall be capable of automatic and manual actuation. Automatic actuation shall be provided by an appropriate number of thermal detectors mounted in series on a stainless steel wire input line to the control head. Manual actuation shall be provided by turning a handle on the primary head and/or by an optional remote pull station with a dedicated stainless steel input line to the control head.

B. The system shall have been tested to the UL Standard for Fire Extinguishing Systems for Protection of Restaurant Cooking Areas, UL 300, and listed by Underwriters Laboratories Inc. It shall be installed in accordance with the National Fire Protection

Association Standard No. 17A Wet Chemical Extinguisher Systems, and No. 96 Standard for the Installation of Equipment for the Removal of Smoke and Grease Laden Vapors from Commercial Cooking Equipment, and comply with all local and/or state codes and standards.

C. Provide pressure activated electric shutoff switch and remote manually operated shutoff switch to all gas and electric cooking equipment located under hood and to exhaust and makeup fans shutoff switch.

D. All piping shall be schedule 40 hot-dipped galvanized steel. Fittings shall be banded pattern, extra heavy galvanized malleable iron threaded with a 2,000 psi WOG rating.

2.03 SUPPLY AND EXHAUST DUCT

A. Furnish and install supply and exhaust ductwork in accordance with the latest edition of NFPA 96 and all applicable local codes.

B. Exhaust ductwork shall be constructed of black steel minimum of 16-gauge thickness. All seams, joints, and penetrations shall have a continuous external weld except where the exhaust duct is connected to the exhaust canopy collar. Connection to the exhaust canopy collar shall be constructed in accordance with NFPA 96.

2.04 ROOFTOP MAKEUP AIR FAN

A. Provide air supply utility set of the single inlet, single width type. Fan housing shall be constructed of heavy gauge galvanized steel with weatherproof coating. Fan shall be provided with weather housing.

B. Fan wheel shall be aluminum, backwards inclined non-overloading. Fan shall be complete with adjustable belt drives, motor and disconnect switch.

C. Provide fan with filter hood for use with 2" thick cleanable filters complete with hood support frame, roof curb adapter for use in the downblast arrangement, backdraft damper and birdscreen.

2.05 ROOFTOP CENTRIFUGAL UPBLAST EXHAUST

A. Provide UL Listed upblast centrifugal fan of aluminum construction complete with non-sparking centrifugal fan wheel.

B. Fan shall come complete with motor and adjustable belt drive, disconnect switch, birdscreen, grease trough, and hinged base (for cleaning).

C. Fan and installation shall comply with NFPA 96.

D. Motor, bearings, and drive shall be isolated from exhaust air. Motor shall be cooled by clean outside air.

PART 3 - EXECUTION - Not Used

END OF SECTION

SECTION 236426 - AIR-COOLED INVERTER SCROLL VARIABLE REFRIGERANT FLOW HEAT PUMP CHILLER

PART 1 – GENERAL

1.1 SUMMARY/SYSTEM DESCRIPTION/ACCEPTABLE MANUFACTURERS

A. Section includes design, performance criteria, refrigerants, controls, and installation requirements for a fully inverter air-cooled scroll heat pump chiller. The package ISHPC shall be provided as specified on the drawings. The package ISHPC shall meet the standards referenced in this specification and meet all local codes in effect.

B. The air-cooled variable refrigerant flow heat pump modular chiller may consist of multiple individual chiller modules. The chiller module shall be available in nominal capacities of 17, 20, 33-, 40-, 50- and 60-ton systems. All systems shall be completely factory wired and tested prior to shipment. Each module shall include a minimum of 2, 4 or 6 compressors matched to 1, 2 or 3 stainless plate and frame evaporator for increased internal redundancy. The quantity of tube in fin air-cooled condensers coil per system shall match the number of compressors allowing each compressor to have a fully independent refrigerant circuit reducing the potential loss associated with a compromised system. Each ISHPC to have a Digital Chiller Controller capable of independent control or plant control of up a maximum of 5 systems. In the event of a malfunctioning circuit the chiller will continue to operate at available maximum capacity with the alarm information made available in the history of the Chiller Control or for a potential BMS. The main chiller PCB and controls shall be capable of independent operation that is needed for a simultaneous heating and cooling application. The main PCB is capable of local and remote control from BMS System. The chiller controls shall have an optional BACnet gateway available to help meet the programming and integration needs of third party BMS systems.

C. Acceptable Manufacturers:

1. LG Electronics

2. Approved Equal, Reference Schedule for Alternate Manufacturers

1.2 REFERENCES

A. Unit shall be rated in accordance with AHRI (Air-Conditioning, Heating and Refrigeration Institute) Standard 550/590, latest edition and all units shall comply with current version of ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers)

SECTION 236426 - AIR-COOLED INVERTER SCROLL VARIABLE REFRIGERANT FLOW HEAT PUMP CHILLER

PART 1 – GENERAL

1.1 SUMMARY/SYSTEM DESCRIPTION/ACCEPTABLE MANUFACTURERS

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B. The air-cooled variable refrigerant flow heat pump modular chiller may consist of multiple individual chiller modules. The chiller module shall be available in nominal capacities of 17, 20, 33-, 40-, 50- and 60-ton systems. All systems shall be completely factory wired and tested prior to shipment. Each module shall include a minimum of 2, 4 or 6 compressors matched to 1, 2 or 3 stainless plate and frame evaporator for increased internal redundancy. The quantity of tube in fin air-cooled condensers coil per system shall match the number of compressors allowing each compressor to have a fully independent refrigerant circuit reducing the potential loss associated with a compromised system. Each ISHPC to have a Digital Chiller Controller capable of independent control or plant control of up a maximum of 5 systems. In the event of a malfunctioning circuit the chiller will continue to operate at available maximum capacity with the alarm information made available in the history of the Chiller Control or for a potential BMS. The main chiller PCB and controls shall be capable of independent operation that is needed for a simultaneous heating and cooling application. The main PCB is capable of local and remote control from BMS System. The chiller controls shall have an optional BACnet gateway available to help meet the programming and integration needs of third party BMS systems.

C. Acceptable Manufacturers:

1. LG Electronics

2. Approved Equal, Reference Schedule for Alternate Manufacturers

1.2 REFERENCES

A. Unit shall be rated in accordance with AHRI (Air-Conditioning, Heating and Refrigeration Institute) Standard 550/590, latest edition and all units shall comply with current version of ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers) 90.1.

B. Unit construction shall comply with ASHRAE 15 Safety Code, UL (Underwriters Laboratories) latest edition, and ASME (American Society of Mechanical Engineers) applicable codes.

C. An operational test, in which the chiller is run is performed at the factory. This test checks for proper operation of fans as well as various controls and safeties, and a certificate of unit testing, indicating successful end-of-line testing is available upon request.

90.1.

B. Unit construction shall comply with ASHRAE 15 Safety Code, UL (Underwriters Laboratories) latest edition, and ASME (American Society of Mechanical Engineers) applicable codes.

C. An operational test, in which the chiller is run is performed at the factory. This test checks for proper operation of fans as well as various controls and safeties, and a certificate of unit testing, indicating successful end-of-line testing is available upon request.

1.3 SUBMITTALS

A. Submit shops drawings and product data in accordance with the specifications.

B. Submittals shall include the following:

1. Total Model Selection Summary for the chiller.

2. Combined System Performance Information (certification is not in scope of AHRI 550-590):

    a) Ambient Temperature Cooling and Heating (°F)

    b) Cooling and Heating Capacity (Ton and MBH)

    c) Power for Cooling and Heating (kW)

    d) EER and COP (Btu/Whr and W/W)

    e) NPLV (Cooling Only Btu/Whr)

    f) Water Temperature Cooling and Heating (in/out °F)

    g) Fluid Flow Rate Cooling and Heating (GPM)

    h) Pressure Drop Cooling and Heating (ftAq)

3. Individual Chiller Specifications to include:

    a) Dimensions (width, height and length)

    b) Weight (lb)

    c) Refrigerant Type, # of circuits and amount required per circuit

    d) Sound Data in accordance with AHRI Standard 370-2015

        i. Sound Power Cooling and Heating

        ii. Sound Pressure Cooling and Heating (5 feet and 30 feet)

e) Compressor Type and Quantity

f) Oil Type and Oil Charge (oz)

g) Evaporator Type, Flow Rate Cooling and Heating, Connection (Size/ Type) and Pressure Drop (ftAq)

h) Fan Motor Type, Flow (CFM) and Power (W)

4. Dimensioned plan and elevation view drawings and location water connections size and type.

5. Electrical Specifications to include Model, Voltage, Phase, Maximum Fuse Amps (MFA) or Maximum Circuit Breaker Amps, Minimum Circuit Amps (MCA), Running Load Amps (RLA), Minimum Start Current (MSC) and Quantity of Independent Circuits.

6. Enhance Sound Information for Cooling and Heating tested in accordance with AHRI Standard 370-2015 (data based on individual unit installation). Only provide full load performance in Heating: charts provided in for Cooling and Heating Mode.

Model	Octave bands, Hz (Sound Power dBA)													Overall A-Weighted Load			
	63	125	200	250	500	1000	1250	2000	2500	4000	5000	8000	10000	100%	75%	50%	25%
ACHH060	36	44	53	66	60	61	61	61	61	59	52	53	49	76	69	63	61

Model	Octave bands, Hz (Sound Pressure 5 Feet dBA)													Overall A-Weighted Load			
	63	125	200	250	500	1000	1250	2000	2500	4000	5000	8000	10000	100%	75%	50%	25%
ACHH060	61	65	75	75	77	76	77	70	68	63	59	56	53	88	83	70	67

Model	Octave bands, Hz (Sound Pressure 30 Feet dBA)													Overall A-Weighted Load			
	63	125	200	250	500	1000	1250	2000	2500	4000	5000	8000	10000	100%	75%	50%	25%
ACHH060	16	24	33	46	40	41	41	41	41	39	32	33	29	56	53	47	45

7. Single-line schematic diagram of line voltage and control system indicating points for field interface/connection.

8. AHRI 550-590 Cooling Performance Data Page to include:

a) Unit information

i. Model

ii. Power Supply (phase, # of wires and volts)

iii. Refrigerant Type

iv. Cooling Capacity (Ton)

v. Quantity of Compressors

vi. Dimensions (length inch, height inch and width inch)

vii. Operating Weight (lb)

viii. Shipping Weight (lb)

ix. Refrigerant Charge (lb)

x. Sound Pressure (AHRI Standard 370-2015 5 Feet and 30 Feet)

b) Cooling Performance Data

i. System KW (W/O Pump)

ii. EER (Btu/Whr)

iii. Full Load Power Input per Ton (kW/usRT)

iv. NPLV (Btu/Whr)

v. 100% EER (Btu/Whr)

vi. 75% EER (Btu/Whr)

vii. 50% EER (Btu/Whr)

viii. 25% EER (Btu/Whr)

c) Evaporator Data

i. Heat Exchanger Structure

ii. Fluid Type and % of Glycol

iii. Water Connection (Size and Type)

iv. Fouling Factor ($h \cdot ft^2 \cdot °F/Btu$)

v. Entering Water Temp (°F)

vi. Leaving Water Temp (°F)

vii. Flow-rate (GPM)

viii. Pressure Drop (ftAq)

d) Condenser Data

i. Heat Exchanger Structure

ii. Refrigerant Type

iii. Altitude (ft above sea level)

iv. Number of Fans

v. Total Air Flow Each (CFM)

vi. Entering Air Temperature (DBT °F)

9. Heating Performance (Tested in accordance with AHRI 550-590 Procedure- not in certification scope of standard)

a) Unit information

i. Model

ii. Power Supply (phase, # of wires and volts)

iii. Refrigerant Type

iv. Heating Capacity (MBH)

v. Quantity of Compressors

vi. Dimensions (length inch, height inch and width inch)

vii. Operating Weight (lb)

viii. Shipping Weight (lb)

ix. Refrigerant Charge (lb)

x. Sound Pressure (AHRI Standard 370-2015 5 Feet and 30 Feet)

b) Heating Performance Data

i. System KW (W/O Pump)

ii. COP (W/W)

c) Evaporator Data

i. Heat Exchanger Structure

ii. Fluid Type and % of Glycol

iii. Water Connection (Size and Type)

iv. Fouling Factor (h·ft²·°F/Btu)

v. Entering Water Temp (°F)

vi. Leaving Water Temp (°F)

vii. Flow-rate (GPM)

viii. Pressure Drop (ftAq)

d) Condenser Data

i. Heat Exchanger Structure

ii. Refrigerant Type

iii. Altitude (ft above sea level)

iv. Number of Fans

v. Total Air Flow Each (CFM)

vi. Entering Air Temperature (DBT °F)

1.4 QUALITY ASSURANCE

A. Qualifications: Equipment manufacturer must specialize in the manufacturing of the products specified and have a minimum of five years of experience with the type of equipment and refrigerant offered.

B. Regulatory Requirements: Comply with the codes and standards specified. Heat Pump Chiller manufacturer's plant must be ISO registered.

1.5 DELIVERY, STORAGE, AND HANDLING

A. The Heat Pump Chiller shall be delivered with condensing section completely assembled and refrigerant charge matching the name plate.

B. Comply with manufacturer's installation instructions for rigging, unloading, and transporting the heat pump chiller modules.

1.6 LIMITED PART ONLY WARRANTY

A. All parts of a qualified system are warranted for a period ending on the earlier to occur of (12) months after the date of original commissioning or eighteen (18) months from ship date of manufacturer. The compressor part only is warranted for an additional (24) month period from the established warranty start date as part of the Limited Part Only Warranty. The limited parts only warranty period, including all parts and the compressor, may be extended

to a total of (60) months or up to (120), months in (12) month increments, by the purchase of additional warranty period increments, which may be only purchased at the time of the original chiller equipment purchase.

B. The qualified system must be commissioned by an individual or company that has successfully completed LG's Chiller System Commissioning and Service training and holds a current government issued license that authorizes that individual or company to service and install HVAC equipment in the state where the chiller is located, if applicable. The system must also be commissioned per the applicable published documents. Service and maintenance of the chiller must also be performed by a qualified individual, as provided in the limited warranty statement.

C. Maintenance of the heat pump chiller equipment while under warranty is mandatory and shall be performed in accordance with the applicable published instructions provided within the installation and operation manual. Proper fluid condition is to be maintained per the installation and operation manual during the warranty period. Annual testing repots and documentation shall be stored and made available upon request by the manufacturer as part of the owner's responsibility and is required under the Limited All Parts Only Warranty.

PART 2 – PRODUCTS

2.1 INVERTER SCROLL HEAT PUMP CHILLER DESCRIPTION

A. Provide and install as detailed on plans Factory-assembled, single-piece air-cooled variable refrigerant flow liquid heat pump chiller(s) in the quantity required. Contained within the unit cabinet shall be all factory wiring, piping, controls, refrigerant charge (R-410A), and special features prior to field start up.

B. The heat pump chiller shall be functionally tested at the factory to ensure components including sensors, wiring, electronics, and microprocessor controls and their function.

C. Chiller shall be heat pump and provide both hot and cold water. Remote mode change option shall be required.

D. Each outdoor unit refrigeration circuit shall include, but not limited to the following components:

i. Refrigerant strainer(s)

ii. Check valve(s)

iii. Inverter driven, medium pressure vapor injection, high pressure shell compressors

iv. Oil separator(s)

v. Accumulator /controlled volume receiver(s)

vi. 4-way reversing valve(s)

vii. Vapor injection valve(s)

viii. Oil Level sensor(s)

ix. Electronic expansion valve(s)

x. Sub-cooler (s)

xi. Vapor Injection Valve(s)

xii. High and low side Schrader valve service ports with caps

xiii. Shared brazed plate water to refrigerant heat exchanger with (4) refrigerant connections and (2) water connections, 316 stainless steel construction with (2) refrigerant circuits and a single water circuit, heat exchanger refrigerant circuits shall be rated to 650 PSIG, water circuit rated to 340 PSIG.

2.2 DESIGN AND PERFORMANCE REQUIREMENTS

A. General: The unit shall be in accordance with the standards referenced in section 1.2 and any local codes in effect.

B. The ISHPC shall have Certified AHRI 550/590 Cooling Performance of 19.46 IPLV and a full load EER of 10.32.

C. Performance: Refer to the schedule of performance as noted in contract documents. The heat pump chiller shall be capable of stable operation to a minimum percentage of 20% of rated capacity of full load.

D. Operating Range: The heat pump chiller shall have the ability to control leaving chilled fluid temperature from 14°F to 68F in cooling and 86°F to 131°F in heating. Unit shall be capable of starting and running at outdoor ambient temperatures from 5°F to 125°F in cooling and -22°F to 95°F in heating mode without additional accessories.

E. Low ambient cooling down to 5°F without the need for field installed additional factory installed accessories.

F. Heating performance to be capable of providing 120°F Leaving Water down to 32°F providing 100% of high temp tested heating capacity per ASHRAE 90.1.

G. Acoustics: Sound pressure level measured in accordance with ISO 3745 Standard for anechoic room rated conditions. The manufacturer shall provide the necessary sound treatment if required to comply with a maximum sound pressure of 56 dBA for both cooling and heating mode based on an A-Weighted Test at 30 feet and 76 dBA at 5 feet A-Weighted Test in accordance with ANSI/AHRI Standard 370-2015. Sound data shall be based on individual unit installation and report to comply with section 1.3.B.6 of this document.

H. The maximum acceptable A-Weighted ANSI/AHRI Standard 370-2015 rated sound pressure performance at 30 feet shall be: Cooling Mode 56 db(A) and Heating Mode 60 db(A) per individual module.

I. Each refrigeration circuit shall contain a 316 stainless steel brazed plate fluid heat exchanger and EEV for sub-cooling and vapor injection operations. All heat exchangers shall maintain independent refrigerant circuits and shall not exceed a combined capacity of 20 tons.

J. INVERTER chiller-heat pump shall be provided with a factory installed fusible plug or rupture disc.

K. Outdoor fan motors shall be BLDC type motors. Speed is to vary based on target refrigeration pressure that will vary based on mode and ambient condition. Targets are determined by internal heat pump chiller control logic.

2.3 HEAT PUMP CHILLER COMPONENTS

A. MATERIALS OF CONSTRUCTION

i. The base must be able to withstand concentrated load. The base must be installed with a maximum gradient of 1/300 inches. The mounted height of the base must be higher than the surface of the fluid or snow and drain holes must be installed around. The height of the base must be set according to the installation environment so that the product is not submersed in fluid or snow.

ii. The default height of the base is 4 inches. The average accumulation of snow fall for area of installation shall be added to the minimum 4” base height.

iii. The casing shall be constructed so that is easy to disassemble and assemble during maintenance/repair. It shall be insulated to prevent condensation, and structurally sound to prevent vibration and/or abnormal noise.

iv. Exterior panels shall have an epoxy coat with a salt spray rating of up to 500 hours.

B. COMPRESSOR/COMPRESSOR COMPONENTS AND SEQUENCE OF OPERATION

i. The R-410A Compressor shall be a hermetic, high-side shell (HSS), commercial grade, compliant scroll direct-drive design. Compressor shall be designed and assembled by the INVERTER chiller-heat pump manufacturer specifically for use in the air source INVERTER chiller-heat pump product line. Third party manufactured, branded, or designed to the INVERTER chiller-heat pump system’s OEM specifications by a third-party manufacturer shall not be acceptable.

ii. Compressor Design: The compressor design shall be of the high-pressure shell scroll type where the internal pressure below the scroll plates of the compressor shall be at the same high pressure and high temperature. The motor shall be cooled by high pressure gas at temperatures above saturation conditions and minimize the mixing of refrigerant liquid with oil in the sump. The system shall employ a high-pressure oil return method returning recovered oil from the oil separator directly into the oil sump of the compressor; oil shall not be allowed to return via the suction line. Bearing surfaces are continually coated with oil. The compressor shall employ an Aero-bearing constructed with high lubricity materials increasing operation time in case of low sump oil level. The fixed and oscillating compressor scroll components shall be made of high grade (GC25) or denser steel material. All scrolls shall be heat treated and tempered. The oscillating scroll shall be finely machined and polished. PVE refrigerant oil shall be used as the sole liquid used to maintain a seal between the high and low sides of the compression chamber. Compressors that require the use of any type of mechanical or wearable sealant material between the moving surfaces of the compression chamber is NOT ACCEPTABLE.

iii. Single frame systems will have 2 inverter compressors, Double Frame systems will have 4 inverter compressors and Triple Frame systems will have 6 compressors. Each compressor has a nominal capacity of 10 tons.

iv. Each refrigeration circuit shall employ a single inverter compressor with a maximum refrigerant charge not to exceed 15.4 lbs.

v. All compressors shall employ high pressure oil return directly into the compressor oil sump. Oil return via the suction line shall not be permitted.

vi. All compressors shall provide, during off cycle, a trickle charge to the windings to keep oil warm. External crankcase heaters shall not be permitted.

vii. All inverter driven compressors within a frame are to operate in unison at the same level. Staging of compressors shall not be permitted with in a frame.

viii. Compressor shall soft start via inverter and shall load only to the required load. Compressors start current for 208-230V the minimum start current shall not exceed 25% of MCA and the 460V the minimum start current shall not exceed 20% of MCA.

ix. The system design is to have a shared evaporator between 2 compressors. System is design to run on any active compressor that are not offline from an error code. External human interface shall not be acceptable if required for emergency operation. Compressor Error messages are available from Main PCB for BMS interface. Local HMI or Chiller Control shall also keep record of compressor error codes as a redundant feature.

x. Vibration prevention isolation rubber grommets shall be installed to isolate compressor from base frame.

xi. Inverter Compressor Control and Sequence: Each compressor shall be equipped with a dedicated inverter compressor drive. The control of multiple compressors using a single drive shall not be acceptable. The frequency variable boundary of inverter scroll compressor shall be minimum 30Hz and maximum 127Hz. The inverter driver controller shall be matched with the physical properties of the compressor. The drive shall be manufactured by the INVERTER chiller-heat pump unit manufacturer. The inverter drive and matching compressor shall have been thoroughly tested as a matched pair. The inverter drive shall be programmed to avoid operating the compressor at any speed that results in harmonic vibration, nuisance noise, or mechanical damage to either the driver or the compressor with power provided that is within the tolerance specification. The compressor inverter drive assembly and software must be designed, manufactured, and supplied by the INVERTER chiller-heat pump product manufacturer. Third party branded inverter driver hardware and/or driver software or inverter driver hardware and/or software provided by a third-party manufacturer to meet OEM specifications shall not be allowed. All inverter drive hardware or software manufactured in, is a product of, or sourced from China, or using a broker or third-party provider as an intermediary that obtains the product from CHINA shall not be acceptable.

xii. Hot Gas Bypass: Includes factory-mounted hot gas bypass valve, solenoid valve, for each circuit.

xiii. Inverter Compressor Refrigerant Flow Control Requirements: An active refrigerant - in-circulation control system consisting of a refrigerant storage container, interconnecting refrigerant piping control valves, pressure transducers, microprocessor control, and software to continuously monitor necessary refrigeration cycle operating parameters to maintain stable cycle operation between minus (-)22°F and 122°F ambient conditions. The refrigerant system operating conditions shall be checked by the algorithm at three-minute intervals and if needed automatically and dynamically remove and store refrigerant to the storage tank or inject refrigerant from the tank into the refrigerant circuit. The algorithm shall adjust the needed refrigerant with input:

1. As the outdoor air temperature changes.
2. System mode of operation changes.
3. The path of refrigerant flow through the outdoor coil is modified.
4. The system's target suction and head pressure control values are adjusted.

xiv. Maximum Hz operation shall be capable of being set at local control or external connection to Unit Main PCB. When educe capacity and or load shedding is desired.

xv. In an event of low load application, below 20% of full rated capacity, an alternating operation should allow for uniform average operation time for each compressor.

xvi. Oil Management: The system shall utilize a high-pressure oil return system to ensure a consistent film of oil on all moving compressor parts at all points of operation. Oil is returned to compressor through a separate high pressure oil injection pipe directly into the oil sump. Oil returned to the compressor via the suction port of the compressor shall not be allowed. Each compressor shall be provided with a high efficiency independent centrifugal cyclone type oil separator, designed to extract oil from the oil/refrigerant gas stream leaving the compressor. The system shall have an oil level sensor in the compressor to provide direct oil level sensing data to the main controller. The sensor shall provide data to main outdoor unit PCB to start oil return mode. The system shall only initiate an oil return cycle if the sensed oil level is below oil level target values as determined by the microprocessor. The system shall display an error if the oil sensor signals low oil level for a period of 130 minutes or longer. A default oil return algorithm shall automatically initiate the oil return mode if the system detects a failure of the oil sump sensor. A fault code shall be reported by the system. Timed oil return operations or systems that do not directly monitor compressor oil level shall not be permitted.

xvii. Vapor Injection Requirement and Description: System shall have a medium pressure gas vapor injection function employed in the heating and cooling modes to increase system capacity when the outdoor ambient temperatures are low and to lower compressor lift when temperatures are high. The compressor vapor injection flow amount shall be controlled by the vapor injection sub-cooling algorithm reset by discharge gas temperatures of the compressor. Pressure differential design shall draw oil from the compressor sump reservoir, pressurize the oil and inject the oil directly to the crankshaft journals maintaining a consistent film of oil between all moving parts. Auxiliary, indirect, or electronically driven oil pumps are not acceptable. The

viscosity property of the PVE oil in the compressor sump shall be maintained regardless of compressor operation and the surrounding ambient temperature. The compressor shall be equipped with control to automatically supply the compressor windings with a trickle charge of electricity enough to maintain the oil temperature above the refrigerant boiling temperature that is automatically activated only when the ambient temperature is below 40F, and the compressor is not running. Addition of external crank case heaters shall not be allowed. Low side shell (LSS) type compressors that use suction vapor to cool the compressor motor shall not be allowed.

xviii. Vapor Injection Sub-cooler: Each compressor circuit shall a factory provided and mounted sub-cooler assembly consisting of a brazed plate type sub-cooling heat exchanger and EEV providing refrigerant sub-cooling modulation control by fuzzy logic of EEV and by mode of operation to provide capacity and efficiency as required. Brazed plate shell & tube heat exchangers shall not be allowed for this function.

xix. Internal Compressor Cooling Requirements and Description: The motor winding insulation shall be designed to operate continuously at a minimum temperature of 180°F without deterioration. The motor cooling system shall be designed to always maintain acceptable operational temperature and, in all conditions, using high pressure, hot refrigerant vapor as motor coolant. Low side shell (LSS) and compressors that use low pressure, low temperature refrigerant gas to cool the motor shall not be allowed.

xx. Active Refrigerant Volume Management: The INVERTER chiller-heat pump system shall be able to operate at all published conditions in cooling or heating mode without the need of adding or removing refrigerant from the system. The air source unit shall be provided with an isolated vessel, interconnecting piping, valves, and sensors to store refrigerant and actively pass refrigerant to (or from) the refrigerant circuit in real time as necessary to maintain stable refrigeration cycle operation. The air source unit microprocessor shall be provided with an algorithm that monitors the INVERTER chiller-heat pump system head pressure, suction pressure, sub-cooling, superheat, compressor speed, high and low side temperatures, chilled water temperatures, hot water temperatures, status of water flow and the load on the system at three minute intervals and if needed, automatically and dynamically remove and store refrigerant to the storage tank or inject refrigerant from the tank into the refrigerant circuit. INVERTER chiller-heat pump systems that cannot perform active refrigerant control are not acceptable.

xxi. Compressor are designed to operate independently. Unless the error code interrupts control power the error of compressor will be broadcasted to BMS front end, and the remaining compressors normal operation is not interrupted.

C. FLUID HEAT EXCHANGERS

i. The fluid heat exchanger shall be a 316 stainless-steel plate and frame type heat exchanger.

ii. As standard, the fluid heat exchanger shell and fluid piping in the chiller heat pump shall be insulated with rigid poly styrene, 1 1/4” thickness and black color.

D. AIR COOLED HEAT EXCHANGER

i. The air-cooled heat exchange arrangement shall be 3-row, 14 FPI (fins per inch), 48 rows. Use wide louvered aluminum fin. The coil(s) shall be sized to provide full heat rejection at a maximum 125°F or -22F minimum ambient temperature for 460V chiller heat pumps and 122°F or -22F for 208-230V chiller heat pumps both at sea level.

ii. The coil(s) shall be factory tested to a minimum 600 psig.

iii. Air Cooled heat exchanger shall include “black fin II” coating, a heavy anti-corrosion treatment protecting the heat exchanger from high salinity, humidity, and pollution. The coating is applied to the fin stock only and the corrosion performance is compliant to meet a 10,000-hour rated salt spray performance test that is conducted in accordance with ASTM B117 standard.

iv. ISO 21207 Salt Spray Test Method B – 10,000 hours performance compliant.

v. ASTM B-117 Acid Salt Test – 900 hours performance compliant.

vi. The Black Fin II coating shall be certified by Underwriters Laboratories and per ISO 21207.

vii. Air Cooled heat exchanger shall be used with 99.9% purity or above phosphorus deoxidized copper without joint and it shall be constructed with Pre-Coated Aluminum fins that are mechanically bonded to increase the thermal transfer surface area. (Cross fin and tube type).

viii. Fan(s) shall be connected directly to driving motor. Motor shall be BLDC type that can increase efficiency. The fan motors shall vary speed to maintain refrigeration head pressure.

ix. Fan design at rated cooling capacity shall not exceed 90% of full or maximum RPM/Hz.

x. System is capable of low noise operation and can reduce sound by up to 3 db.

E. ELECTRONIC EXPANSION VALVES

i. EEV’s shall be used during adiabatic-expansion process within the refrigerant cycle to expand high pressure liquid refrigerant at both the Air-cooled heat exchanger and the fluid heat exchanger exit thereby converting to low temperature/low pressure state.

ii. LEV’s (linear expansion valves) shall be activated to adjust refrigerant amount according to fluid heat exchanger load during cooling operation.

iii. Based on data from various sensors installed in the chiller heat pump, the micro-processor shall be able to analyze operation status of the system and compressor shall control the optimum refrigerant amount linearly.

iv. By applying electric pulse signal (up to 2,000 pulses) to the stepping motor, it shall be able to adjust refrigerant flow and superheat and sub-cooling.

F. CONTROL SYSTEM

i. Controller shall operate to control the overall system at optimal condition with a micro-computer unit installed in the chiller heat pump, and be able to control electronic expansion valve and inverter driven compressor(s) based on the 4 measured values: suction gas pressure, discharge gas pressure, discharge gas temperature, and heat exchanger refrigerant temperature

ii. Control system shall include sensor(s) functionality connected to the heat pump chiller and the varying operation mode status.

iii. Heat Pump Chiller shall be equipped with self-protection devices and system protection functionality.

iv. Internal flow switch is included as standard, installed, and wired.

v. External contact closure indicating pump operation is required and is to be hard wired to heat pump chiller main PCB.

vi. Continued heat operation during defrost is required on systems that are at or above 33 tons or double and triple frame modules.

vii. Target Evaporator temperature is set based on leaving water temperature allowing for energy savings as leaving water temps settings can change with the application and time of day.

viii. If the unit is off and not running due to error the service tool provided by the manufacture shall be capable of downloading the last 180 seconds of operational time the chiller was running helping to diagnose field service issues that may arise.

G. HEAT PUMP CHILLER UNIT CONTROLLER AND DISPLAY (HMI- HUMAN MACHINE INTERFACE)

i. The HMI control interface can be applied for simple product control. Relocation & re-installation of HMI controller shall be possible.

ii. The HMI may be relocated up to 1500 wire feet away from chiller heat pump.

iii. Black box function shall retain the last 180 seconds of operational data prior to a failure.

iv. Scheduled operation shall be possible via the HMI.

v. High ambient control box for operation in ambient temperatures to 125°F (52°C).

vi. The controller shall be equipped with a cycle indication display to directly monitor refrigerant pressure conditions for refrigerant cycle and high-pressure gas safety management.

vii. Chiller heat pump interface controller/HMI shall be capable of networking up to 5 chiller heat pump modules and control & monitor up to five (5) chiller heat pumps as one system if desired. For systems larger than five modules several parallel networks of up to five modules may be installed and controlled via BMS. Up to 99 parallel systems are capable of being controlled by a third party BMS.

viii. Optional Heat Pump Chiller Control BACnet Gateway. The Control Gateway shall include Niagara4.7 or later based hardware, with a minimum 512 MB DDR SDRAM, 2GB total eMMC flash storage with user space set at 1GB, 1 RS485 port, 2 10/100 MB Ethernet ports, with BACnet and Modbus network protocol capability. Standard interface is BACnet/IP. BACnet/MSTP is an optional solution and should be specified if needed.

H. WATER PIPING AND FLOW REQUIREMENTS:

i. The heat pump chiller is to be capable of a minimum flow is at a 20-degree delta between entering and leaving water and maximum flow capable of a 4-degree delta between entering and leaving water temperatures.

ii. The heat pump chiller is provided with a factory installed flow switch that is prewired as a required safety circuit for operation.

iii. A strainer (50 Mesh or above) shall be provided, by others, and installed in the supply fluid piping to each module to prevent solid bodies or particles from entering the fluid heat exchanger. Strainer shall be installed on leveled pipe and shall be serviceable by individual manual isolation valves, by others, that permit each strainer to be removed and allowing the remaining modules to continue to operate.

iv. Flexible joints shall be installed at the inlet and outlet pipes of each module.

v. Fluid piping and needed insulation shall be properly specified by engineer and be compliant per local code for both process and comfort cooling applications.

vi. Piping is to be installed and service valves provided so that each heat pump chiller module shall have service valves and the isolation of an independent module in the array shall not affect the flow and operation of the additional heat pump chiller modules that work together to create the heat pump chiller plant. On a four-pipe system this is required for both hot and cold water.

vii. Maximum water pressure design for the system is 142 psi.

viii. All water piping and accessories to be independently supported from the equipment and the dead weight of the pipe or accessories is not transmitted or supported by the equipment in any way.

ix. The following fluid specification shall be maintained; Water- PH 7-9, total dissolved solids less than 1000PPM, hardness (CaCo3) 30-500 PPM, alkalinity (CaCo3) 0-500 PPM, chlorides less than 200 PPM, sulfates less than 200 PPM. Water with 25% glycol- PH 7-9, total dissolved solids 1000 -10,000 PPM, conductivity 1000-5000 PPM, hardness (CaCo3) 30-500 PPM, alkalinity (CaCo3) more than 500 PPM, chlorides less than 200 PPM, sulfides less than 200 PPM. Other fluid conditions shall be as defined in specifications provided elsewhere.

END OF SECTION 236426

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SECTION 23 73 14 - MODULAR INDOOR AIR HANDLING UNIT (LOW PRESSURE)

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Belt-Driven Air Handling Units - 3 square feet to 21 square feet of coil face area.

1.02 REFERENCES

A. NFPA 90 A & B - Installation of Air Conditioning and Ventilation Systems and Installation of Warm Air Heating and Air Conditioning Systems

B. L 181 - Factory-Made Air Ducts and Connectors

C. UL 1995 - Heating and Cooling Equipment

1.03 SUBMITTALS

A. Submit unit performance data including capacity, nominal and operating performance.

B. Submit HVAC specifications for unit and accessories describing construction, components and options.

C. Submit shop drawings indicating overall dimensions as well as installation, operation and service clearances. Indicate lift points and recommendations and center of gravity. Indicate unit shipping, installation and operating weights including dimensions.

D. Submit data on electrical requirements and connection points. Include recommended wire and fuse sizes or MCA, sequence of operation, safety and start-up instructions.

1.04 REGULATORY REQUIREMENTS

A. Unit shall be UL Listed and meet UL 1995 requirements.

1.05 SEQUENCING AND SCHEDULING

A. Sequence work.

B. Schedule work under the provisions of Section 01 30 00.

1.06 HANDLING

A. Comply with the manufacturer’s installation instructions for rigging, unloading, and transporting units.

B. Store units indoors and protect units on site from damage. Shipping package is not weatherproof. Leave factory shipping covers in place until installation.

1.07 WARRANTY

A. Provide a full parts warranty for one (1) year from start-up or 18 months from shipment, whichever occurs first.

PART 2 - PRODUCTS

2.01 MANUFACTURERS - AIR HANDLING UNITS

A. Approved Manufacturers:

1.	Trane	LPC
2.	York	CS
3.	Carrier	39L or 39T
4.	McQuay	SeasonMaster LS

2.02 BELT-DRIVEN AIR HANDLING UNITS - 3 SQUARE FEET TO 21 SQUARE FEET OF COIL FACE AREA

A. The manufacturer shall provide unit arranged for draw-through application. Blow-through is not acceptable due to condensate carryover.

B. Hydronic Coils: Copper tubes mechanically expanded into evenly spaced aluminum fins rated for 300 psig and 200 degrees F. Coils shall be tested with 450 psi air pressure under water at the factory. Coils shall be capable of being rotated in the field for left hand or right hand connection.

C. Drain Pan: The IAQ drain pan(s) shall be constructed of smooth, corrosion resistant material. Acceptable materials include polymer or 304 stainless steel. The bottom of the drain pan shall be sloped in two planes that pitch the condensate to the drain connection. Units without 2-way sloped drain pans shall coat drain pans with anti-microbial treatment. To eliminate bottom sweating under drain pan, the manufacturer shall provide drain pan with double wall internally insulated construction.

D. Access: The entire air handler shall be constructed of G60-U galvanized steel removable panels. The removal of side panels shall not affect the structural integrity of the unit. The Contractor shall be responsible to provide connection flanges and all other framework that is needed to properly support the unit.

E. Insulation - Matte: Interior surface of unit casing acoustically and thermally lined with a minimum of 1", R-value 4.2, 1.9 lb./cu. ft. density glass fiber with high density facing. Insulation shall be UL Listed and meet NFPA-90A and UL 181 requirements.

F. Fans: The fan shall consist of a centrifugal forward curved wheel, dynamically balanced and belt driven. Dual wheels are not acceptable due to center bearing being inaccessible for repair or replacement.

G. Motors: The motor shall be open drip-proof with permanently sealed ball bearings. Motors shall be factory run tested.

1. All motors shall be factory-installed and wired. Field installation of motors shall not be acceptable.
2. Motors shall be selected to operate continuously at 104 degrees F (40 degrees C) ambient without tripping on overloads. Motors shall have a +/-10% voltage utilization range.
3. Motors shall be selected with a minimum of 15% safety factor greater than the fan brake/horsepower (e.g. 4.75 BHP would require a nominal 7-1/2 HP motor). The motor service factor shall not be used as part of the safety factor.

H. Filter - High Capacity: Easily removable 2" thick 30% efficient filter for both room air and outside air. Separate filters for outside air and room air are not acceptable. All units shall use standard filter sizes.

I. Fresh Air/Return Air Dampers - Mixing Box: Damper with blade seals and jamb seals, capable of varying proportion of mixed air from 100% room air to 100% outside air.

J. Control Interface: The unit manufacturer shall provide actuators and sensors for connection to a field supplied thermostat. Unit shall be factory run tested and end devices shall be factory wired to terminal strip in an external junction box and tested for wiring continuity.

1. The thermostatic control package shall include:
   a. 24 VAC transformer
   b. Disconnect switch
   c. Fan contactor
   d. Terminal strip
   e. Control enclosure
   f. Analog mixing section damper actuator
   g. Low Limit Thermostat: Low limit thermostat shall have a vapor tension element located in the discharge airstream of the unit.
   h. Fan Status Switch: Fan status switch shall be a differential pressure switch which will close when pressure across the fan indicated fan operation.
   i. Filter Status Switch: Filter status switch shall be a differential pressure switch which will close when the pressure across the filter indicates that the filter requires replacement.
   j. Condensate Float Switch: Condensate float switch shall be mounted in the drain pan and open if the drain pan begins to fill.

2.03 AIR HANDLER FEATURES

A. High Capacity Filter Section: Provide filter section with maximum filter face velocity of 300 at design air flow. Filter section shall utilize standard size filters. Filter access panels shall be provided on both sides of unit. Casing shall comply with requirements in specification sections 2.02 E and F.

B. Mixing Section: Provide a mixing box section for economizer control. Heavy gauge low leak damper blade with bladed and jamb seals shall be used. Damper shall be factory

linked together and use a double ended drive rod which allow for field mounting of actuator on inside or outside of unit right or left side. Access panels shall be provided on both sides of unit. Casing shall comply with the requirements in sections 2.02 E and F of this specification.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that surfaces are ready to receive work and opening dimensions are as indicated on shop drawings.

3.02 INSTALLATION

A. Install in accordance with the manufacturer's instructions.

B. Provide units with shut-off valve on supply and lockshield balancing valve on return piping.

3.03 CLEANING

A. Clean work.

B. After construction is completed, including painting, clean exposed surfaces of units. Vacuum clean coils and inside of cabinets.

C. Install new filters.

END OF SECTION

SECTION 236426 - VARIABLE REFRIGERANT FLOW DOAS HVAC SYSTEMS

PART 1 – GENERAL

1.1 Dedicated Outdoor Air System – Split Compact (500 – 2000 CFM)

1. Provide outside air unit as manufactured by LG or pre-approved equal.
2. Alternate manufacturers must be pre-approved and shall be subject to compliance with all the requirements listed in this specification.
3. Project is based on the specified equipment. Any additional costs associated with using alternate manufacturer's equipment shall be borne by the installing contractor or equipment provider.
4. This section includes units connectable to remote condensing units for heating/cooling/dehumidification and for outdoor installation.
5. Heat source shall be from remote heat pump condenser. Minimum entering air temperature in heating shall be 14F.
6. Cooling source shall be split system remote condenser with invertor compressors.
7. Airflow arrangement shall be Outdoor Air only.
8. Each unit shall be constructed in a horizontal configuration and shall incorporate additional product requirements as listed in this specification.
9. Manufacturers
    a) Available Manufactures: Subject to compliance with specifications contained within this document, manufacturer’s offering products that may be incorporated into the work include but are not limited to LG

A. Casing

1. Exterior wall constructed using 18 gauge SGCC Z22 galvanized steel with internal closed cell Polyethylene foam insulation

B. Cabinet Assembly

1. All the internal assemblies shall use 18 gauge SGCC galvanized steel.
2. All specified components and internal accessories factory installed shall be tested and prepared for single-point high voltage connection.
3. Unit shall be fully assembled at the factory and consists of the following:
    a) Single wall metal cabinet
    b) 1” PE foam, external insulation with R-value of 3.55

c) DX Main coil

d) Hot gas reheat coil

e) Condensate drain pan

f) Condensate drain pump

g) Integrated Heat Recovery Box

h) Sensors

i) Supply air blower assembly

j) Filter assembly for DX Main coil with 2” Thick MERV 8 filters

k) Electrical control center.

4. Main DX (Evaporator) Coil

a) Evaporator coil shall be (silver) soldered or brazed into the refrigerant system. Coil shall be constructed of copper tubing, permanently bonded to aluminum fins and enclosed in a SGCC steel frame.

5. Hot Gas Reheat Coil

a) Reheat coil shall be (silver) soldered or brazed into the refrigerant system with factory installed modulating valve. Coil shall be constructed of copper tubing, permanently bonded to aluminum fins and enclosed in a SGCC steel frame.

6. Control panel / connections

a) Units shall have an electrical control center where all high and low voltage connections are made. Control center shall be constructed to permit single-point high voltage power supply connections.

7. Condensate drain pan:

a) Drain Pan shall be an integral part of the unit. Pan shall be formed of welded 18 gauge SGCC galvanized sheet material with proprietary pre-painted (Dawn Gray-RAL 7037) and provided with a drain connection for a field provided P trap.

b) Drain pan shall be sloped in two directions to provide positive draining and drain connector shall be sealed at penetration through cabinet wall.

8. Condensate drain pump

a) Integrated condensate drain pump with overflow switch shall operate when unit is in cooling or dehumidification modes

9. Control and Diagnostics

a) The DOAS system shall be controlled by an onboard digital controller (DDC) that indicates both owner-supplied settings and fault conditions that may occur.

b) The DDC shall be programmed to indicate the following faults:

i. Global alarm condition (active when there is at least one alarm)

ii. Outdoor Unit (condenser) Error Alarm

iii. Supply Air Temperature Low Limit Alarm

i. Sensor #1 Out of Range (outside air temperature)

ii. Sensor #2 Out of Range (supply air temperature)

iii. Sensor #3 Out of Range (cold coil leaving air temperature)

10. Sensors are considered to be part of various optional operational modes or device controllers and are to be factory supplied and installed as specified by the design engineer.

a) Factory install sensors:

i.Supply Air Temperature Sensor

ii.Outdoor Air Temperature Sensor

iii.Outdoor Air Humidity Sensor

b) Field Supplied and Installed Sensors (Optional)

i. Supply Duct Air Temperature Sensor

ii. Supply Duct Air Humidity Sensor

iii. Space Temperature Sensor

iv. Space Humidity Sensor

v. Space CO2 Sensor

C. Blower/Motor Assembly

1. Blower section construction Supply Air

a) Direct drive motor(s) and blower(s) shall be assembled on a 13 gauge galvanized steel platform

b) Blower assemblies shall be statically and dynamically balanced and designed for continuous operation at maximum rated fan speed and horsepower.

c) Fan: Direct drive, Sirroco fan with painted steel wheels statically and dynamically balanced and AMCA certified for air and sound performance.

d) Blower section motor source quality control

i. Blower performance shall be factory tested for flow rate, pressure, power, air density, rotation speed and efficiency.

ii. Ratings are to be established in accordance with AMCA 210, “Laboratory Methods of Testing Fans for Rating.”

2. Motors

a) General

i. Blower Motors shall be BLDC motors, Supply fan motor shall have Auto CFM modulation control or RPM control. Auto CEM Control is enabled with factory mounted differential pressure sensor. Microprocessor controller shall set CFM value and supply fan motor will modulate to maintain target CFM value even as external static pressure changes

D. Filter Assembly

1. Units shall have supply final air filter shall be of 2 inch MERV 8

E. Unit Controls

1. The unit shall be constructed so that it can function as a stand-alone heating and cooling system controlled by factory-supplied controllers and sensors, or it can be operated as a heating and cooling system controlled by a Building Management System (BMS).

2. This unit shall be controlled by a factory-installed microprocessor programmable controller (DDC) that is connected to various optional sensors.

3. Supply fan shall be configured for Constant Volume

a) Capacity Control: Control air volume by RPM percentage

b) CFM Control: Fan to follow target CFM set by user and automatically adjust for external static pressure changes

4. Operating protocol

a) The DDC shall be factory-programmed for Bacnet IP and Modbus RTU standard.

b) Must be compatible with LG AC Smart Controller.

c) Graphical Web UI required.

5. Embedded web page with complete web user interface to allow full remote control and monitoring of unit.

6. Alarm Recording: Controller shall store all alarm events

7. Alarm Operating Snapshot Controller shall store operating inputs and outputs at time of alarm

F. Submittals

1. Product Data: For each type or model include the following:

a) Complete fan performance curves for Supply Air.

b) Sound performance data for Supply Air.

c) Motor ratings, electrical characteristics, motor and fan accessories.

d) Performance ratings for all coils.

e) Dimensioned drawings for each type of installation to include location of attached ductwork and service clearance requirements.

f) Estimated gross weight of each installed unit.

g) Installation, Operation and Maintenance manual (IOM) for each model.

h) Microprocessor Controller (DDC) specifications to include available options and operating protocols. Include complete data on all factory-supplied input devices. Modbus RTU and BACnet IP are standard protocols. They must be compatible with LG AC Smart Controller.

G. Connections

1. In all cases, industry Best Practices shall be incorporated. Connections are to be made subject to the installation requirements shown above.

a) Piping installation requirements are specified in Division 22 (Plumbing). Drawings indicate general arrangement of piping, fittings and specialties.

b) Duct installation and connection requirements are specified in Division 23 of this document.

c) Electrical installation requirements are specified in Division 26 of this document.

H. Examination

1. Prior to start of installation, examine area and conditions to verify correct location for compliance with installation tolerances and other conditions affecting unit performance. See unit IOM.

2. Examine roughing-in of plumbing, electrical and HVAC services to verify actual location and compliance with unit requirements. See unit IOM.

3. Proceed with installation only after all unsatisfactory conditions have been corrected.

I. Installation

4. Installation shall be accomplished in accordance with these written specifications, project drawings, manufacturer's installation instructions as documented in manufacturer's IOM, Best Practices and all applicable building codes.

J. Coordination

1. Coordinate size and location of all building penetrations required for installation of each unit and associated plumbing and electrical systems.

2. Coordinate location of water system fittings to ensure correct positioning for condensate drain pipe.

3. Coordinate sequencing of construction of associated plumbing, HVAC, electrical supply and sheet metal contractor.

K. Quality Assurance

1. Source Limitations: Obtain unit with all appurtenant components or accessories from a single manufacturer.

1. For the actual fabrication, installations, and testing of work under this section, use only thoroughly trained and experienced workers completely familiar with the items required and with the manufacturer's current recommended methods of installation.

2. Product Options: Drawings must indicate size, profiles, and dimensional requirements and are to be based on the specific system indicated. Refer to Division 1 Section "Product Requirements".

3. Certifications

a) Blower shall be AMCA Certified for airflow.

b) Entire unit shall be ETL Certified per U.L. 1995 and bear an ETL sticker.

L. Field Quality Control

1. Manufacturer's Field Service

a) Engage a factory authorized service representative to inspect field assembled components and equipment installation, to include electrical and piping connections.

2. Reports results to A/E in writing

a) Inspection must include a complete startup checklist to include (as a minimum) the following: Completed Start-Up Checklists as found in manufacturer's IOM.

END OF SECTION 236426

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SECTION 23 82 19 - FAN COIL UNITS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, and Section 23 00 00 - HVAC General apply to all work specified in this section.

B. The scope of work described in these Specifications and/or indicated on the drawings shall include the furnishing of all materials, equipment, appurtenances, accessories, connections, labor, etc. required for the complete installation of fan coil units specified herein. All work shall be accomplished by workmen skilled in the various trades involved.

C. The Drawings and Specifications are complementary to each other and what is called for by one shall be as binding as if called for by both. If a discrepancy exists between the Drawings and Specifications, the higher implied cost shall be included in the bid, and the Architect shall be notified of the discrepancy in writing.

D. Refer to Section 23 00 00 - HVAC General for the submittal and approval requirements regarding the fan coil units specified herein.

1.02 DESCRIPTION OF WORK

A. Fan coil units (FCU) shall be provided to meet the minimum capacities as scheduled at the indicated conditions, shall meet all constraints of construction and shall comply with all Specification Sections.

B. Fan coil units of one manufacturer have been used as the basis of design. Any modification to piping, controls, electrical connections and structural supports that result from the use of equipment by any other manufacturer, shall be coordinated with all other trades. A layout drawing shall be included with the product data submittal showing that the substituted equipment has been coordinated. This coordination shall occur before delivery of the equipment from the manufacturer. Any modifications shall be performed without incurring any additional cost to the Contract.

1.03 QUALITY ASSURANCE

A. Fan coil units: Product of manufacturer regularly engaged in production of components who issues complete catalog data on total product offering.

B. Fan coil units shall be UL listed and shall comply with NFPA 90A.

C. Fan coil units shall be tested and certified in accordance with AHRI Standard 440 Room Fan-Coils.

1.04 ACCEPTABLE MANUFACTURERS

A. Vertical fan coil units (closet type) shall be International, JCI, Carrier, Trane, or Daiken.

B. Horizontal fan coil units shall be International, JCI, Carrier, Trane, or Daiken.

PART 2 - PRODUCTS

2.01 VERTICAL FAN COIL UNITS

A. Fan coil units shall be the vertical closet type. Units shall be provided with cabinet, chilled water cooling coil, hot water heating coil, ni-chrome fused electric heating coil with contactors and factory installed fused disconnect switch, drain pan, filter, fan motor and drive and valve package.

B. The unit cabinet shall be fabricated of reinforced 18-gauge continuous galvanized steel. The interior of the cabinet shall be fully insulated with 1/2" thick, 2 lb./cu. ft. density fiberglass insulation having a black vapor barrier coating conforming to NFPA 90A.

C. The water coils shall be constructed of seamless copper tubing mechanically expanded into aluminum fins. Tube wall thickness shall be not less than 0.016". Cooling coils shall be a minimum of four (4) rows. Heating coils shall be a minimum of two (2) rows. The coils shall be factory leak tested at 300 psig.

D. Beneath the cooling coil there shall be an stainless steel drain pan. The underside of the drain pan shall be covered with 1/2" thick elastomeric insulation. The copper condensate drain line shall be rolled into the pan and sealed prior to coating of the pan and sealed with waterproof fire-rated mastic. Provide overflow protection with a water level detection device in the drain pan wired to shut the unit down upon detection of water.

E. Filters shall be 1" thick pleated type; MERV 8.

F. The fan motor shall be of the permanent split capacitor type ECM, suitable for the voltage shown on the Electrical Drawings, and shall have built-in thermal overload protection. Motors shall be 3-speed, 1,050 RPM maximum, with a factory installed disconnect switch.

G. Electric heating coils shall be open grid resistance type. The heater shall be provided with a factory-mounted fused disconnect. All heaters shall have capacity as scheduled when supplied with electrical power as shown on the Electrical Drawings.

H. All units shall be listed by Underwriters Laboratories Inc. and shall bear the UL Label.

I. Manufacturer shall submit octave band analysis from a recognized independent testing laboratory. Operating sound level shall not exceed NC30 based on medium speed and NC35 maximum on high-speed fan in a “medium hard” room.

J. Each fan coil unit shall be furnished with a valve package consisting of 2-ball type shutoff valves, an automatic flow control valve (Griswold, Auto Flow or Flow Design or approved equal) and a 2-way motorized valve. The fan coil unit located at the end of the riser shall include a 3-way control valve.

K. Refer to Section 23 09 00 - Automatic Controls for temperature sensor/thermostat and control functions for vertical fan coil units.

2.02 HORIZONTAL FAN COIL UNITS

A. Fan coil units shall be of the single zone, horizontal draw through type. Units shall be provided with chilled water cooling coil, electric resistance heating coil, factory installed fused disconnect switch, electric motor and drive equipment, filter, and cabinet.

B. Unit chassis shall be constructed 18-gauge steel with channel-formed panel edges and be provided with hinged access panel for access to all interior components.

C. Water coils shall be constructed of aluminum fins mechanically bonded to seamless copper tubes. Coils shall be factory leak tested 300 psi. All coils shall be certified for compliance with provision of AHRI Standards of water coils. Cooling coils shall be a minimum of four (4) rows. Heating coils shall be a minimum of two (2) rows.

D. Fan wheels shall be the centrifugal forward-curved, double width type.

E. 3-speed motors shall have an integral thermal overload protection and start at 78% of rated voltage. Motors shall be factory run tested in assembled unit prior to shipping. Motor cords shall be detachable by a locking pronged connector.

F. Filters shall be 1" thick pleated type; MERV 8.

G. A water seal shall be provided in the drain line at the unit outlet. Trap shall be constructed as indicated. Drain line shall be installed with a slope of not less than 1/8" per foot down in the direction of flow. For units located above ceilings, provide a secondary drain pan 3" larger on all sides than the unit. Provide overflow protection with a water level detection device in the drain pan wired to shut the unit down upon detection of water.

H. Manufacturer shall submit octave band analysis from a recognized independent testing laboratory. Operating sound level shall not exceed NC 30 based on medium speed and NC 38 maximum on high-speed fan in a “medium hard” room.

I. Each fan coil unit shall be furnished with a valve package consisting of 2-ball type shutoff valves, an automatic flow control valve (Hays Mesurflo, Griswold, or Flow Design or approved equal) and a 2-way motorized (modulating) control valve.

J. Refer to Section 23 09 00 - Automatic Controls for temperature sensor/thermostat and control functions for horizontal fan coil units.

2.03 HOSE KITS

A. A hose kit shall be provided for each vertical and horizontal fan coil unit. Each kit shall include an automatic flow control valve with pressure/temperature test ports, two flexible braided stainless-steel hoses, a Y-type strainer with hose end valve, a two- or -three position motorized isolation valve (where indicated) and two ball valves. Hose kits shall

be factory assembled, leak tested, and shipped carded, tagged (matching the equipment ID tag) and shrink wrapped. Hose kits shall be Hays Mesurflo or equal by Griswold Controls, IMI Flow Design, Nexus or approved equal. The hose kits shall be warranted for one year from the shipping date. The automatic flow control valve shall be warranted by the manufacturer for no less than three years from date of purchase.

1. The automatic flow control valve shall automatically control flow rates with a +/- 10% accuracy over an operating pressure differential range of 2-80 PSI.
2. Pressure Rating: 400 PSIG minimum
3. Minimum/Maximum Operating Temperature: 32°F - 225°F.
4. The valve's internal control mechanism shall consist of an elastomeric diaphragm and high-performance polymer orifice plate or a passivated stainless-steel one-piece cartridge with segmented port design and full travel linear coil spring. Flow control cartridges shall be replaceable without disconnecting the valve form the piping system.
5. Dual pressure/temperature test ports (Schrader valves) for verifying the pressure differential across the cartridge and system temperature shall be included.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Fan coil units shall be installed in strict conformance with the manufacturer's recommendations and the Contract Documents.

B. Fan coil units shall not be operated during construction. Start-up units prior to commissioning/test and balance.

C. Protect units with MERV 8 temporary filter media on the return air inlet to prevent construction dust and debris from entering the unit from start-up to final turnover.

D. A second set of filters shall be installed after the unit has been cleaned and testing and balancing has been completed.

3.02 TRAINING

A. Train the owner/operator in proper operation and maintenance procedures of the fan coil units. Training shall include an in-depth review of the IOM manual.

END OF SECTION

SECTION 23 82 33 - ELECTRIC DUCT HEATERS

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

B. A wiring diagram depicting layout and connections of electrical components within the control cabinet shall be affixed to the inside of the control cabinet door.

C. A rating plate label shall be affixed to the exterior of the control cabinet door which states the manufacturer, model number, serial number, volts, amps, phase, frequency, control volts, volt-amps and minimum airflow requirements.

1.02 WORK INCLUDED

A. Receipt, unloading, handling, proper storage and protection from damage of all materials.

B. Layout and coordination of work with other trades.

C. The work under this section shall include all labor, materials, accessories, services, and equipment necessary to furnish and install electric duct heaters, complete, as indicated on the drawings and as specified herein.

1.03 WARRANTY

A. Heaters shall be warranted against defects in materials or workmanship for one year from the date of installation, not to exceed 18 months from date of manufacture when installed in accordance with the installation instructions and properly maintained.

PART 2 - PRODUCTS

2.01 ELECTRIC DUCT HEATERS

A. Electric duct heaters shall be full flange type or slip-in type (if space for side access removal is available).

B. Duct heaters shall be Chromalox, Indeeco, Brasch, or Tutco.

C. Duct heaters shall be constructed in accordance with provisions of the National Electrical Code and shall be UL or ETL tested and listed to UL Standard 1996 – Standard for Electric Duct Heaters.

D. All frame members, terminal boxes and associated metal parts shall be fabricated from heavy gauge galvanized steel.

E. Control cabinet shall be constructed of heavy gauge galvanized steel with multiple knockouts for field wiring. The control cabinet shall have a solid cover of heavy gauge galvanized steel held in place with hinges and tool-release latches. Two latches shall be employed when the latched side of the cover is 48 inches wide or wider.

F. Duct heaters shall be furnished with a factory installed combination non-fused disconnect switch and door lock to disconnect power to the heater. The door lock shall prevent the door from being opened unless the switch is in the off position. A separate toggle switch shall be provided to break any incoming remote control sources. A disconnecting magnetic control circuit is required.

G. Duct heater shall be supplied with primary over temperature protection by built-in disc type automatic reset thermal cutouts and secondary over temperature protection by built-in disc type manually resettable thermal cutouts. These devices must function independently of one another and are not acceptable if series connected in the control circuit wiring.

H. All heating elements shall be constructed of nickel/chromium resistance wire with ends terminated by means of staking and heliarc welding to machine screws. Heating element support structure shall consist of galvanized steel wire formed and constructed to support ceramic bushings through which the heating element passes.

I. Heating banks shall be connected for phase and voltage as indicated on the electrical drawings. Three phase duct heaters shall consist of equal rated heating elements internally connected to provide a balanced three phase load.

J. Duct heater capacity control shall be by Silicon Controlled Rectifier (SCR) or electronic step controller for quiet and precise temperature control. For proportionally controlled heaters (SCR) the fan should be set to continuous operation when heat is called for. Proper air mixing and precise temperature control cannot be maintained unless the circulating air remains at a constant flow/volume.

K. Duct heater shall be furnished with differential pressure switch (paddle switch is not acceptable), an automatic reset high limit cutout, a thermal cutout with manual reset, control contactors and control transformer (120 volts maximum) all factory pre-wired to a common power terminal.

L. Over-current protection by means of factory-installed fusing within the control cabinet shall be provided for heaters rated at more than 48 amps. Heating elements shall be subdivided and fused accordingly.

M. No transition of ductwork (up or down), restriction, or damper will be allowed within 4'-0” of the upstream side of the heating coil.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Electric duct heaters shall be installed in accordance with manufacturer’s installation instructions and details.

B. Allow sufficient clearance to fully open control panel door(s) for servicing.

1. Clearances for electric duct heaters and low voltage control panels located above ceilings: the contractor shall coordinate and plan the work to allow for a clear space in front of all electric duct heater control panels of 42” deep x 30” wide (or the width of the panel whichever is greater). The control panel door shall be allowed to open at least 90 degrees.

C. Supply power wiring must be sized appropriately for the full load of the heater and any accessories that may be connected via a branch circuit.

D. Control inputs should be verified to be compatible with the controls supplied with the heater prior to installation.

E. All wiring connections, lugs, and fasteners should be checked for tightness before energizing the heater for the first time. Instruct the owner to periodically check these connections during the lifetime of the heater. Vibration during shipping can cause fasteners to loosen. Failure to tighten connections could cause an over-heating condition when the heater is energized.

F. Ensure that all duct filters, dampers, and louvers are installed prior to operation. Airflow switch operation may be hindered if insufficient back-pressure is created downstream of the heater.

END OF SECTION

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SECTION 23 82 39 - ELECTRIC UNIT HEATERS

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

1.02 WORK INCLUDED

A. Receipt, unloading, handling, proper storage, and protection from damage of all materials.

B. Layout and coordination of work with other trades.

C. The work under this section shall include all labor, materials, accessories, services, and equipment necessary to furnish and install electric unit heaters complete as indicated on the Drawings and as specified herein.

D. Refer to the drawings for approved manufacturers.

1.03 QUALITY ASSURANCE

A. Electric heaters shall be constructed in accordance with provisions of the National Electrical Code and shall be UL or ETL tested and listed to UL Standard 2021 – UL Standard for Safety Fixed and Location-Dedicated Electric Room Heaters.

PART 2 - PRODUCTS

2.01 UNIT HEATERS

A. Unit shall be of the horizontal or vertical discharge fan-forced propeller type.

B. Casing shall be constructed of heavy gauge die-formed, furniture grade steel, phosphate coated and finished in baked enamel.

C. The heating element shall be aluminum-finned with a copper clad steel sheath.

D. Fan shall be direct drive propeller type designed specifically for unit heater applications.

E. The motor shall be totally enclosed, thermally protected, continuous duty type selected to match airflow requirements.

F. Unit shall be provided with the manufacturer’s standard mounting bracket for either ceiling or wall mounting as required.

G. Unit shall be equipped with individually adjustable horizontal discharge louvers.

H. Wiring shall be designed for a single source power connection with elements, motor and control circuits subdivided and fused to conform to the latest National Electrical Code, OSHA, and Underwriters Laboratories Inc. standards. All three phase heaters shall have balanced phases. A factory wired non-fused disconnect switch shall be provided. Control circuit voltage shall not exceed 120 volts.

I. Unit heater shall be equipped with an automatic reset linear thermal cut-out, a fan delay switch, and control circuit transformer.

J. Thermostat shall be unit mounted or wall mounted as shown on the Drawings.

2.02 CEILING HEATERS

A. Unit shall be of the vertical discharge fan-forced type.

B. Housing shall be constructed of heavy gauge steel with a baked-on powder coat finish.

C. The grille shall be constructed of 18-gauge powder coated steel.

D. The heating element shall be the block-finned type with parallel steel fins.

E. Fan shall be the direct drive propeller or vane axial type.

F. The motor shall be totally enclosed, thermally protected, continuous duty type selected to match airflow requirements.

G. Unit shall be provided with the manufacturer's standard mounting hardware for ceiling mounting.

H. Wiring shall be designed for a single source power connection with elements, motor and control circuits subdivided and fused to conform to the latest National Electrical Code, OSHA, and Underwriters Laboratories standards. A factory wired non-fused disconnect switch shall be provided. Control circuit voltage shall not exceed 120 volts.

I. Ceiling heater shall be equipped with a manual reset thermal limit (integral thermostat) or automatic reset thermal limit (remote wall mounted thermostat), a fan delay switch, and control circuit transformer.

PART 3 - EXECUTION

3.01 INSTALLATION

A. All units shall be installed in strict accordance with the manufacturer's installation instructions.

B. In areas where heaters are used for freeze protection, thermostat setpoint shall be adjusted to 40^{o}F.

END OF SECTION

SECTION 23 82 39.19 - ELECTRIC WALL HEATERS

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. All work specified herein shall be accomplished in accordance with the applicable requirements of Section 23 00 00 - HVAC General.

1.02 WORK INCLUDED

A. Receipt, unloading, handling, proper storage and protection from damage of all materials.

B. Layout and coordination of work with other trades.

C. The work under this section shall include all labor, materials, accessories, services, and equipment necessary to furnish and install wall heaters complete as indicated on the Drawings and as specified herein.

PART 2 - PRODUCTS

2.01 WALL HEATERS

A. Unit shall be completely factory assembled, wired, tested and shipped as a single assembly; capacity shall be as indicated on the Drawings.

B. Unit heaters shall be constructed in accordance with provisions of the National Electrical Code and shall be UL or ETL tested and listed to UL Standard 2021 – UL Standard for Safety Fixed and Location-Dedicated Electric Room Heaters.

C. Front grille shall be 16-gauge steel or aluminum finished in baked enamel or anodized with downflow discharge louvers.

D. Element shall consist of helically coiled nickel chromium alloy resistance wire enclosed in corrosion resistant sheaths.

E. Controls shall include fan delay switch, built-in thermostat, automatic reset thermal overload switch and a non-fused disconnect power switch.

F. Unit shall be designed to either recess into the wall or for surface mounting as scheduled, and shall include all mounting accessories.

G. Unit shall be Raywall, QMark, Markel, Berko, Indeeco or approved equal.

PART 3 - EXECUTION

3.01 INSTALLATION

A. All units shall be installed in strict accordance with the manufacturer’s recommendations.

END OF SECTION