## I. SPECIAL REQUIREMENTS

1. Definitions

   a. "Provide" is a term used for convenience throughout this Specification and means "to furnish, install and connect completely in the specified or in an approved manner the item and/or material described."

   b. The word "Contractor" or “Mechanical Contractor” denotes the firm who will contract with the Owner to accomplish the work defined in the Plans and Specifications.

   c. The words "Owner" and "Wesleyan University" may be used interchangeably throughout this specification.

   d. The words "Engineer" and Saren Engineering, Inc. may be used interchangeably throughout this Specification.

2. Rules, Regulations and Permits

   a. All details of the modifications shall be made in strict accordance with the latest edition of the National Electrical Code, OSHA, The National Fire Protection Association "Life Safety Code", the Plumbing, Heating and Building Codes of the State of Connecticut, the Connecticut Boiler Code, the ASME Boiler Code, the requirements of the City of Middletown, and all other State and Local codes which apply. Nothing in this Specification shall be interpreted as an infringement of such codes.

   b. The Contract Documents shall govern whenever they exceed code requirements.

   c. All contractors shall obtain and pay for their own permits and certificates required by Local and State authorities and/or governing bodies having jurisdiction over this work.

3. Repairs During Guarantee Period

   a. The Contractor shall replace or repair at his own expense any part of the work performed or furnished under his Section of the work which proves defective in workmanship or material within a period of one year following acceptance of his work by Owner. This shall also include the expense of making good all work of other Subcontractors and/or property and operations of the Owner, which has been destroyed or damaged due to defective work or defective material, including the cost of emergency hookups necessary to keep the system in operation until permanent repairs have been made.

4. Rigging, Hauling and Storage

   a. All cost for rigging, hauling, storage, proper protections, labor, etc., necessary to delivery and set in place all equipment specified in the following Sections shall be borne by the Contractor.

5. Manufacturer's Instructions

   a. The Contractor is responsible for installing all equipment, which he furnishes in accordance with the Manufacturer's instructions or requirements for proper operation and maintenance, and shall include the cost of all labor and materials necessary to accomplish this. Installation requirements and details of different manufacturers may vary; therefore, the Contractor shall check each manufacturer's equipment before submitting.

   b. If such instructions or requirements conflict with the Plans and Specifications, the Contractor shall obtain instructions from the Engineer before proceeding.

   c. Equipment shall be installed in accordance with the Plans and Specifications wherever either exceeds the Manufacturer's requirements.

6. Equipment Clearances

a. Whether or not shown in detail or dimensioned on the Drawings, no equipment shall be installed in such a manner that it or parts of it cannot be properly maintained or serviced.

7. Coordination and Scheduling

a. The Contractor shall place orders for materials and equipment sufficiently in advance of required delivery at the job site to allow adequate time for: (1) review and processing of shop drawings, (2) coordination with other related shop drawings, and (3) coordination with other trades prior to installation.

b. Connections to existing services, existing equipment and other work requiring shutdown of Owner's systems or equipment must be scheduled and coordinated with the Owner. Where existing services must be maintained in operation the contractors shall provide any necessary temporary services or by-passes as required and approved.

c. No conduit, boxes, piping, etc. shall be installed until the entire run has been checked for clearance, and the work has been coordinated between all of the trades. Each tradesman shall be responsible for taking his own field measurements, maintaining proper clearances from the equipment and work of other trades, and for coordinating his work with that of all other trades. Furnish all necessary information, dimensions, templates, etc. in order that a properly coordinated job will result.

8. Protection and Maintenance of Equipment and Systems Prior to Final Acceptance

a. Maintain all new equipment and systems installed under this contract until time of final acceptance by Owner whether such equipment is in use or not, unless by written agreement the Owner consents to take over maintenance and operation of such equipment.

b. The Contractor shall see that proper instructions to the Owner's operating personnel are completed before any part of the work is turned over to the Owner for operations and maintenance.

9. Lubrication

a. All items requiring lubrication of any kind shall be left freshly and fully lubricated at the time the job is turned over to the Owner. The Contractor shall be responsible for assuring that no equipment is turned on nor is used for temporary service, nor is run for testing purpose without proper lubrication.

b. Furnish the Owner complete printed lubrication instructions for each piece of equipment and points to be lubricated, including frequency of attention. This information shall be included as part of the Operating and Maintenance Manuals.

10. Tests Prior to Substantial Completion

a. Tests shall be attended by representatives of Contractor, equipped with instruments required to demonstrate proper functioning of systems as specified. Provide all labor, material, instruments and services of manufacturer's representatives necessary for performance of tests. Demonstrate the following:

1. Equipment installed and operating in accordance with manufacturer's specifications and instructions and with these specifications.

2. Safety and operating controls operating as specified.

3. Systems properly flushed, vacuumed, cleaned, and free of contaminants.

4. Motors equipped with proper overload protection, and not operating under overload.

b. Provide all parties with adequate notice prior to scheduling tests.

c. Test shall be repeated until satisfactory results are obtained.

11. Maintenance and Operating Instructions Manual

    a. Submit maintenance and operating instructions for all equipment supplied under this contract having moving parts. All data shall be assembled in a suitable binder and indexed. Manuals shall be delivered to Owner at least two (2) weeks prior to Instruction Period.

    b. Operating instructions shall be specified for each system and each piece of equipment. Include copies of posted instructions. Shop drawings and other literature may be included in the Manual as supplementary information, but not as a substitute for bonafide operating and maintenance data. Include names, addresses and telephone numbers of the manufacturer's representative and service company, for each piece of equipment, so that service or spare parts can be readily obtained.

        1. List replacement parts.

        2. Include lubrication instructions and schedule, with types of lubricant to be used.

        3. Include service procedures.

        4. List local service company locations for major equipment.

    c. Electrical schematics including all changes that occur during installation and start-up shall be included in the maintenance manuals.

12. Instructions to Owner

    a. Provide instruction to the Owner's operating personnel. Include locating and identifying operating, safety and maintenance components for all the systems; instruction in the operation and function of all equipment and systems.

    b. These instructions shall be given the Owner just prior to substantial completion of the job, when all systems are fully operative and final adjustments have been completed.

13. Underwriter's Laboratories Labels

    a. All electrical equipment and electrical components shall bear labels attesting to U.L. approval. All other materials, devices and products, for which there is listing in the U.L. Product Directories, shall bear a U.L. label.

14. Equal Materials and Substitutes

    a. In addition to the requirements for the Contract conform to the following:

        1. All manufacturers, whether named or proposed, will be required to conform, with modifications if necessary, to all conditions of the base specification insofar as performance, efficiency, special accessories and materials are concerned.

        2. The submittal of a shop drawing containing items at variance with the Contract Documents does not constitute a proper request for substitution. Requests directly from manufacturers or suppliers are not acceptable.

        3. The burden is upon the Contractor, supplier and manufacturer to satisfy the Engineer that the proposed substitute is equal to, or superior to, the item specified, and that the required performance, efficiency, quality, appearance, space, delivery, and the intent of the Specifications will be equaled or exceeded.

15. Shop Drawings

    a. Provide six sets of shop drawings. All shop drawings will be reviewed and approved by the Engineer and Owner prior to start of installation.

b. Mark all Shop Drawings and cuts with Job Name and the Specification Section and Paragraph.

c. Shop drawings should contain the following information:

1. Equipment identification corresponding to equipment numbers shown on the Drawings.

2. Materials of construction, metal gage, thickness and finish.

3. Clearances required for maintenance or access.

4. Performance data and operating characteristics.

5. Electrical characteristics.

6. All descriptive and product data necessary to verify compliance with these Specifications.

7. U.L. label or listing.

8. Clearly delete all accessories, options, special features or materials which are not being furnished.

d. Submit samples of materials when requested by Engineer.

16. Cutting, Painting, and Patching

a. All required cutting and patching is the responsibility of the Contractor. All portions of the building and its systems that are disturbed must be returned to "good" condition in a neat and workmanlike manner.

b. All areas in which cutting or patching is done must be repainted by the Contractor to match adjacent areas as closely as possible.

17. Asbestos and Mercury

a. The existing insulation on pipes and equipment on which work will be done under this contract may contain asbestos. All new tie-ins, capping and control installations shall be so arranged by the Contractor to minimize the amount of existing insulation that must be disturbed and/or removed.

b. If insulation containing or likely to be containing asbestos is encountered, the Owner shall be informed. All removal of insulation containing asbestos shall be the responsibility of the Owner.

c. All equipment, devices, and materials supplied for this project shall not contain asbestos or mercury.

18. Owner's Use of Facilities

a. Portions of the facility (1st floor) will be operated by the Owner for the duration of the project. The Lower Level will be shutdown for most of the construction period. The Contractor shall be responsible for coordinating the work so that the facility will suffer minimal interruption of normal operations and minimal conflict with work being done by other contractors and/or the Owner.

b. When short-term system shut-downs are required for tie-ins etc., the Contractor shall notify the Owner at least 48 hours in advance.

c. If it is not possible to schedule temporary system shut-downs during normal business hours, the Contractor shall be responsible for arranging the shut-downs outside normal business hours.

19. Ambient Conditions

a. All equipment and control devices furnished as part of this project shall be rated by the respective

manufacturer, and capable of continuous operation, in an ambient temperature of 120°F.

## II. EQUIPMENT

A. PIPING MATERIALS

1. Chilled Water and Heating Hot Water Piping

   a. Pipe - Black steel, type A53 or A106, seamless or ERW. Standard weight. Beveled or grooved ends.

   b. Fittings – 2 1/2" and larger, wrought steel buttwelded; 2" and smaller, Class 150, malleable iron threaded. Fittings - for welded pipe, all sizes, standard weight black steel welding pattern conforming to ANSI B16.9, and B16.25.

   c. Joints - screwed joints shall be made up with Teflon pipe thread tape, Teflon liquid or other approved non-hardening joint compound applied to male thread only. Welded joints shall be made by oxyacetylene or electric arc process.

   d. Any pipe 1-1/4" and larger may be welded; no pipe larger than 2" shall be screwed.

2. Drain Piping

   a. PVC Plastic Pipe: ASTM D 1785, Schedules 40, plain ends.

   b. PVC Plastic Pipe Fittings: Socket-type pipe fittings, ASTM D 2466 for Schedule 40 pipe.

      1. PVC Solvent Cement: ASTM D 2564. Include primer according to ASTM F656.

3. Small dia ChW, City Water, Domestic Hot Water, and Condenser Water

   a. Pipe - Comply with ASTM B88, Type L drawn temper copper tubing.

   b. Fittings - Comply with ANSI B16.22, wrought copper, streamlined pattern.

   c. Joining Materials - Comply with ASTM B32, 95-5 tin-antimony, lead free solder filler metals. Staybrite #8.

B. PIPE HANGERS

1. Manufacturer: Subject to compliance with requirements, provide hangers and supports of one of the following:

   a. Fee & Mason Mgs. Co., Div. of A-T-O Inc.

   b. Anvil International, Inc.

   c. National Pipe Hanger Corp.

2. Pipe Hangers, Supports, and Components: Factory-fabricated of materials, design, and manufacture complying with MSS SP-58.

   a. Galvanized, Metallic Coatings: For piping and equipment that will not have a field-applied finish.

   b. Nonmetallic Coatings: On attachments for electrolytic protection where attachments are in direct contact with copper tubing.

3. Thermal-Hanger Shield Inserts: 100-psi minimum compressive-strength, ASTM C552, Type 1, rigid cellular

glass insulation, encased in sheet metal shield.

a. For Trapeze or Clamped System: Insert and shield cover entire circumference of the pipe.

b. For Clevis or Band Hanger: Insert and shield cover lower 180 degrees of pipe.

c. Insert Length: Extend 2 inches beyond sheet metal shield for piping.

4. Mechanical-Anchor Fasteners: Insert-type attachments with pull-out and shear capacities appropriate for supported loads and building materials where used.

5. Structural Steel: Comply with American Society for Testing and Materials (ASTM) Standard A 36/A 36M, steel plates, shapes, and bars, black and galvanized.

6. Bolts and Nuts: Comply with ASME B18.10 or ASTM A 183, steel, hex-head, track bolts and nuts.

7. Washers: Comply with ASTM F 844, steel, plain, flat washers.

C. VALVES

1. All valves in insulated lines shall have stem extenders to provide clearance from insulation.

2. Chilled Water and Heating Hot Water

a. Ball Valves 2-1/2" and Smaller: Rated for 150 psig saturated steam pressure, 600 psig WOG cold non-shock; two-piece construction; with bronze body conforming to ASTM B62, standard port, chrome-plated bronze ball, replaceable "Teflon" or "TFE" seats and seals, blowout-proof stem, zinc plated steel lever handle with securely attached vinyl grip and threaded ends. Provide solder ends for domestic water service. Valve shall be Apollo type 70-100 or 70-200 or approved equal.

b. Swing Check Valves 2" and Smaller: Comply with MSS SP-80; Class 125, cast-bronze body and cap conforming to ASTM B62; with horizontal swing, Y-pattern, and bronze disc; and having threaded ends. Provide valves capable of being reground while the valve remains in the line. Provide Class 150 valves meeting the above specifications, with threaded end connections, where system pressure requires or where Class 125 valves are not available. Valve shall be Crane type 37 or approved equal.

c. Calibrated Balancing Valves: Ball type, 125 psig working pressure, 250°F maximum operating temperature. Valves shall have calibrated orifice, connections for portable differential pressure meter with integral seals, and be equipped with a memory stop to retain set position. Valves 2" and Smaller: Bronze body, threaded end connections. Valves 2-1/2" and Larger: Cast-iron or steel body, flanged connections. Subject to compliance with requirements, provide calibrated balancing valves by one of the following:

1. ITT Bell & Gossett; ITT Fluid Technology Corp.

2. Taco, Inc.

D. PIPING SPECIALTIES

1. Y-Pattern Strainers for Chilled Water and Heating Hot Water Piping: Provide strainers full line size of connecting piping, with ends matching piping system materials. Screens shall be Type 304 stainless steel, with 3/64" perforations at 233 per square inch.

a. Provide strainers with 125 psig working pressure rating for low and medium pressure applications, and 250 psig working pressure rating for high pressure applications.

b. Provide temporary strainer baskets for use during construction and startup. Temporary baskets to have 1/32" perforations.

c. Threaded Ends 2" and Smaller: Bronze body, screwed screen retainer with centered blowdown fitted with pipe plug.

d. Flanged Ends 2-1/2" and Larger: Cast-iron body, bolted screen retainer with off-center blowdown fitted with pipe plug.

e. Subject to compliance with requirements, provide strainers by one of the following:

1. Armstrong Machine Works

2. Metraflex Co.

3. Spirax Sarco

2. Provide manual air vents rated for 150 psig working pressure and 225°F operating temperature. Vents shall have bronze bodies, non-ferrous internal parts, 1/8" discharge connection and 1/2" inlet connection. Vents shall be manually operated with screwdriver or thumbscrew.

3. Sleeves: The following materials are for wall, floor, slab, and roof penetrations:

a. Steel Sheet Metal: 0.0239-inch minimum thickness, galvanized, round tube closed with welded longitudinal joint.

b. Steel Pipe: ASTM A 53, Type E, Grade A, Schedule 40, galvanized, plain ends.

E. METERS AND GAGES

1. Subject to compliance with requirements, manufacturers offering bimetal dial thermometers and pressure gages that may be incorporated into the Work include, but are not limited to, the following:

a. Dresser Industries, Inc.; Instrument Div.

b. Marsh Bellofram.

c. Trerice: H.O. Trerice Co.

2. Gage Case Diameter:

a. Gages located less than 10 feet above floor level: Provide gages with case diameters not less than 5” in diameter.

b. Gages located at or more than 10 feet above floor level: Provide gages with case diameters not less than 8” in diameter.

3. Thermometers, general:

a. Accuracy: Plus or minus 1 percent of range span, or plus or minus one scale division to a maximum of 1.5 percent of range span.

b. Scale Ranges: Temperature ranges for thermometers shall be as follows: Chilled Water/Heating Water: 0° to 160°F with 2 F° scale divisions.

c. All thermometers to be mounted in thermowells.

4. Bimetal thermometers:

a. Type: Direct-mounted, bimetal, universal angle.

b. Case: 5-inch diameter, stainless steel with heavy-duty glass lens.

c. Adjustable Joint: Provide 180° adjustment in vertical plane, and 360° adjustment in horizontal plane, with locking device and finish to match case.

d. Element: Bimetal coil.

e. Scale: Satin-faced, non-reflective aluminum, with permanently-etched markings.

f. Stem: Stainless steel for separable socket, length to suit installation.

5. Thermometer wells: Provide brass or stainless steel wells, pressure-rated to match piping system design pressure. Provide 2" extension for insulated piping and threaded cap nut with chain permanently fastened to well and cap.

6. Pressure gages and fittings:

a. Provide gages complying with American Society of Mechanical Engineers (ASME) Standard B 40.1, Grade A, phosphor bronze bourdon-tube type, with bottom connection.

b. Case: Drawn steel or brass, with 4-1/2" diameter glass lens.

c. Connector: Brass, 1/4" male NPS.

d. Scale: White coated aluminum, with permanently-etched markings.

f. Accuracy: Plus or minus 1 percent of range span.

g. Range: Conform to the following: Select pressure gage range equal to approximately twice the normal operating pressure.

h. Accessories:

1. Snubber: 1/4" NPS brass bushing with corrosion-resistant porous metal disc. Disc material shall be compatible with the fluid whose pressure is being measured, and suitable for the design pressure of the gage.

2. Gage cock: 1/4" stainless steel gage cock, Trerice 735-9 MFG. All gages shall have gage cocks.

F. DUCTWORK AND ACCESSORIES

1. Sheet Metal Materials: Provide sheet metal in thicknesses indicated, packaged, and marked as specified in American Society for Testing and Materials (ASTM) Standard A 700. Ductwork shall be fabricated from galvanized sheet steel complying with ASTM A 527, lock-forming quality. Coating designation shall be G 90. Provide mill-phosphatized finish for surfaces of ducts exposed to view. Reinforcement Shapes and Plates: Unless otherwise indicated, provide galvanized steel reinforcing where installed on galvanized sheet metal ducts. Tie Rods: Galvanized steel, 1/4" minimum diameter for 36" length or less; 3/8" minimum diameter for lengths longer than 36".

2. Acoustic Duct Liner: Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.

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

1. Armacell LLC.

b. Liner shall have the following characteristics:

1. Thickness: 1 inch.

2. Density: 3 to 6 lb/cu. ft.

3. EPA registered biocide in air stream surface meeting requirements of ASTM C 1338 and ASTM G 22.

4. Thermal Performance: Maximum thermal conductivity (K-value) shall be 0.25 BTU-in/hr-sq. ft.-F° at a mean temperature of 75°F.

5. Acoustic Performance: Minimum sound absorption coefficient at 125 Hz is 0.08 and at 250 Hz is 0.22.

6. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

c. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

d. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct. Provide fasteners that do not damage the liner when applied as recommended by the manufacturer, that do not cause leakage in the duct, and will indefinitely sustain a 50-pound tensile dead load test perpendicular to the duct wall.

1. Fastener Pin Length: As required for thickness of insulation, and without projecting more than 1/8 inch into the air stream.

2. Adhesive for Attachment of Mechanical Fasteners: Comply with the "Fire Hazard Classification" of duct liner system.

3. Sealing Materials: Joint and Seam Sealants, General: The term sealant used here is not limited to materials of adhesive or mastic nature, but also includes tapes and combinations of open weave fabrics and mastics. Joint and Seam Tape: 2" wide, glass-fiber-reinforced. Tape Sealing System: Woven-fiber tape impregnated with a gypsum mineral compound and a modified acrylic/silicone activator to react exothermically with the tape to form a hard, durable, airtight seal. Joint and Seam Sealant: One-part, non-sag, solvent-release-curing, polymerized butyl sealant complying with FS TT-S-001657, Type I; formulated with a minimum of 75% solids.

4. Hangers and Supports:

a. Building Attachments: Concrete inserts, powder actuated fasteners, or structural steel fasteners appropriate for building materials. Do not use powder actuated concrete fasteners for lightweight aggregate concretes or for slabs less than 4" thick.

b. Hangers: Galvanized sheet steel, or round, uncoated steel threaded rod. Strap and Rod Sizes: Conform with Table 4-1 in Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) "HVAC Duct Construction Standards, Metal and Flexible", 1985 edition, for sheet steel width and gage and steel rod diameters.

c. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

d. Trapeze and Riser Supports: Steel shapes conforming to ASTM A 36. Where galvanized steel ducts are installed, provide hot-dipped-galvanized steel shapes and plates.

5. Rectangular Duct Fabrication: Fabricate rectangular ducts with sheet steel in accordance with SMACNA "HVAC Duct Construction Standards", Tables 1-3 through 1-19, including their accompanying details and specifications. Conform to the requirements in the referenced standard for metal grade (lockforming), material strength, thickness, reinforcing types and intervals, tie rod applications, and joint types and intervals. Fabricate

rectangular ducts in lengths appropriate to reinforcement and rigidity class required for pressure classification. Provide materials that are free from visual imperfections such as pitting, seam marks, roller marks, stains, and discolorations. Static Pressure Classifications: Except where otherwise indicated, construct duct systems to the following pressure classifications:

a. Supply Ducts: 3" water gage.

b. Return Ducts: 2" water gage, negative pressure.

c. Exhaust Ducts: 2" water gage, negative pressure.

Crossbreaking or Cross Beading: Crossbreak or bead duct sides that are 19" and larger and are 20 gage or less, with more that 10 sq. ft. of unbraced panel area, as indicated in SMACNA "HVAC Duct Construction Standard", Figure 1-4, unless they are lined or are externally insulated.

6. Rectangular Duct Fittings: Fabricate elbows, transitions, offsets, branch connections, and other duct constructions in accordance with SMACNA "HVAC Duct Construction Standards", 1985 edition, Figures 2-1 through 2-10.

7. Flexible Connectors: Flame-retardant or noncombustible fabrics, coatings, and adhesives complying with Underwriters Laboratories (UL) Standard 181, Class 1.

   a. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2" wide attached to two strips of 2-3/4" wide, 24 gage, galvanized sheet steel or 0.032-inch thick aluminum sheets. Select metal compatible with connected duct system. Fold and crimp metal edge strips onto fabric as illustrated in Sheet Metal and Air Conditioning Contractor's National Association (SMACNA) HVAC Duct Standard, 1st Edition, Figure 2-19.

   b. Fabric: Provide glass fabric, double-coated with polychloroprene. Minimum Weight: 26 oz. per square yard. Tensile Strength: 480 lb per inch in the warp, and 360 lb per inch in the filling. Service Temperature: Minus 40 to plus 200°F.

   c. Available Manufacturers: Subject to compliance with requirements, manufacturers offering flexible connections which may be incorporated in the work include, but are not limited to, the following:

      1. American/Elgen Co.; Energy Div.
      2. Duro Dyne Corp.
      3. Ventfabrics, Inc.

8. Duct Accessory Hardware: Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

9. Duct Silencers: Factory-fabricated and tested, rectangular silencers with performance characteristics and physical requirements as indicated.

   a. Fire Performance: Adhesives, sealants, packing materials, and accessory materials shall have fire ratings not exceeding 25 for flame-spread index and 50 for smoke-developed index when tested according to ASTM E 84.

   b. Casing Material: Fabricate casings with a minimum of 0.034 inch (22 gage) thick, solid galvanized sheet metal for outer casing and 0.022 inch (26 gage) thick, ASTM A 653/A 653M, G90, perforated galvanized sheet metal for inner casing.

   c. Sheet Metal Perforations: 1/8 inch diameter for inner casing and baffle sheet metal.

   d. Fill Material: Inert and vermin-proof fibrous material, packed under not less than 5 percent compression. Erosion Barrier: Polymer bag enclosing fill and heat-sealed before assembly.

e. Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations.

1. Do not use nuts, bolts, or sheet metal screws for unit assemblies.
2. Lock form and seal or continuously weld joints.
3. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
4. Reinforcement: Cross or trapeze angles for rigid suspension.

f. Source Quality Control:

1. Acoustic Performance: Test according to ASTM E 477.
2. Record acoustic ratings, including dynamic insertion loss and self-noise power levels with an airflow of at least 2000 fpm face velocity.
3. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or 6-inch wg static pressure, whichever is greater.

h. Dynamic Insertion Loss at 1000 Hz: 24 dB.

i. Pressure Drop: 0.23” w.g. at a face velocity of 975 feet per minute.

j. Available Manufacturers: Subject to compliance with requirements, manufacturers offering air silencers which may be incorporated in the work include, but are not limited to, the following:

1. Vibro-Acoustics.

10. Shop Application of Liner in Rectangular Ducts:

a. Adhere a single layer of indicated thickness of duct liner with 90% coverage of adhesive at liner contact surface area. Multiple layers of insulation to achieve indicated thickness is prohibited.

b. Apply a coat of adhesive to liner facing in direction of airflow not receiving metal nosing.

c. Butt transverse joints without gaps and coat joint with adhesive.

d. Fold and compress liner in corners of rectangular ducts or cut and fit to assure butted edge overlapping.

e. Longitudinal joints in rectangular ducts shall not occur except at corners of ducts, unless the size of the duct and standard liner product dimensions make longitudinal joints necessary.

f. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely around perimeter; at 3 inches from transverse joints, and at intervals not exceeding 18 inches longitudinally.

g. Secure transversely-oriented liner edges facing the airstream with metal nosings that are either channel or "Z" profile or are integrally formed from the duct wall at the following locations:

1. Fan discharge.

2. Intervals of lined duct adjacent to unlined duct.

h. Terminate liner with duct build-outs installed in ducts to attach dampers, turning vane assemblies, and other devices. Fabricated build-outs (metal hat sections) or other build-out means are optional; when used, secure build-outs to the duct wall with bolts, screws, rivets, or welds.

11. Fire Dampers:

a. Provide fire dampers labeled in accordance with Underwriters' Laboratories (UL) Standard 555 "Standard

for Fire Dampers".

b. Fire Rating: 1-1/2 or 3 hours as indicated.

c. Frame: Type A or Type B; fabricated with roll-formed, 21-gage, galvanized steel; with mitered and interlocking corners.

d. Mounting Sleeve: Factory-installed or field-installed galvanized steel, of length to suit application.

1. Minimum Thickness: 0.056" (16 gage) or 0.138" (10 gage) thick as indicated.

2. Omit sleeve where damper frame width permits direct attachment of perimeter mounting angles on each side of the wall or floor, and thickness of damper frame meets sleeve requirements.

e. Mounting Orientation: Vertical or horizontal as indicated.

f. Blades: Provide roll-formed, interlocking, 21-gage galvanized steel blades. In place of interlocking blades, provide full-length, 21-gage galvanized steel blade connectors.

g. Horizontal Dampers: Include a blade lock and stainless steel negator closure spring.

h. Fusible Link: Provide replaceable, fusible link rated at 160°F to 165°F unless otherwise indicated.

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

1. Air Balance, Inc.
2. Arrow Louver and Damper; Div of Arrow United Industries, Inc.
3. Louvers and Dampers, Inc.

12. Volume Dampers:

a. General: Provide factory-fabricated volume-control dampers complete with required hardware and accessories. Stiffen damper blades to provide stability under operating conditions. Provide locking device to hold single-blade dampers in a fixed position without vibration. Close duct penetrations for damper components to seal duct consistent with pressure class. Extend axles full length of damper blades. Provide bearings at both ends of operating shaft.

b. Frames: Provide hat-shaped galvanized steel channels, minimum of 16 gage, and with mitered and welded corners. Provide frames with flanges where indicated for attaching to walls. Provide flangeless frames where indicated for installation in ducts.

c. Blades: Provide roll-formed, galvanized steel blades, minimum of 16 gage.

d. Provide galvanized steel blade axles, tie bars, and brackets.

e. Quadrant Locks: Provide for each damper, quadrant lock device on one end of shaft; and end bearing plate on other end for damper lengths over 12". Provide extended quadrant locks and end bearing plates for externally insulated ductwork.

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

1. Air Balance, Inc.
2. Arrow Louver and Damper; Div of Arrow United Industries, Inc.
3. Louvers and Dampers, Inc.

G. INSULATION

1. Chilled Water and Heating Hot Water Piping:

   a. Type: Mineral-fiber, preformed pipe insulation (ASTM C 547 Type 1, Grade A) with all-service jacket. Maximum thermal conductivity shall be 0.26 BTU-in/hr-sq ft-°F at 75°F mean temperature. For insulation of existing and new piping at all first floor fan coil units provide ½" thick armaflex.

   b. Thickness:

      1. Chilled Water Piping: Thickness: 1" thick for pipe sizes up through 4"; and 1.5" thick for pipe sizes 5" and up. Jacket with vapor barrier is required and shall comply with ASTM C 921, Type I.

      2. Heating Hot Water Piping: 1.5" thick for pipe sizes up through 3"; and 2" thick for pipe sizes greater than 3".

   c. Provide rigid cellular glass insulation under all pipe shields at hangers.

   d. Pipe Fitting Covers: Factory-fabricated, pre-molded PVC.

2. Duct:

   a. Type: Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type II for sheet materials.

   b. Thickness: 2" thick.

   c. Adhesives: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.

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

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

      1. Armacell LLC; AP Armaflex.

H. EQUIPMENT

1. Modular Air Handling Units

   a. Modular indoor air handling units shall be factory assembled and include supply fan, return fan, motors and drive assemblies, heating coil, chilled water coil, reheat coils, dampers, plenums, filters, condensate pans, , thermal insulation, control devices, and accessories. Units may be demounted in the field to modular sections. Dimensions/configuration must be as shown on the drawings to fit into the available space. Access to the installation space is restricted; the contractor shall be responsible for coordination of AHU configuration for any required partial disassembly and reassembly to install the unit in the new fan room.

   b. Cabinet

      1. Materials: Formed and reinforced double-wall insulated panels, fabricated to allow easy and quick removal for access to internal parts and components, with joints between sections sealed. Outside Casing: Galvanized steel, 0.0635 inch thick minimum (16 gage). Inside Casing: Galvanized steel, 0.0396 inch thick minimum (20 gage). Floor Plate: Galvanized steel, 0.1382 inch thick minimum (10 gage). Reinforced points of support for setting units. Cover casing and frame with protective finish on both sides.

      2. Insulation: Comply with NFPA 90A or NFPA 90B. Insulate unit casing from air entrance to coils, to air outlet from unit. Insulate framing angles exposed to air stream. Securely attach insulation, of

sufficient thickness and density to prevent condensation from forming on unit casing. Protect insulation against deterioration from air currents. Materials: ASTM C 1071 with coated surface exposed to airstream to prevent erosion of glass fibers or spray injected foam (R = 12.5 hr·ft2·ºF/Btu). Thickness: 2 inches. Thermal Conductivity (k-Value): 0.26 at 75ºF mean temperature. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50, when tested according to ASTM C 411. Liner Adhesive: Comply with NFPA 90A or NFPA 90B and ASTM C 916. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet. Location and Application: Encased between outside and inside casing.

3. Access Panels and Doors: Same materials and finishes as cabinet, complete with hinges, latches, handles, and gaskets. Inspection and access panels and doors shall be sized and located to allow periodic maintenance and inspections. Provide access panels and doors in the following locations: Fan Section: Doors. Access Section: Doors. Coil Section: Doors. Damper Section: Doors. Filter Section: Doors to allow periodic removal and installation of filters.

4. Condensate Drain Pans: Formed sections of stainless-steel sheet complying with requirements in ASHRAE 62. Fabricate pans with slopes in two planes of sufficient size to collect condensate from cooling coils (including coil piping connections and return bends) when units are operating at maximum catalogued face velocity across cooling coil. Double-Wall Construction: Fill space between walls with foam insulation and seal moisture tight. Insulation shall prevent condensate formation on unit exterior. Drain Connections: Both ends of pan. Of sufficient size to remove coil condensate. Pan-Top Surface Coating: Elastomeric compound. Units with stacked coils shall have an intermediate drain pan or drain trough to collect condensate from top coil.

c. Fan Section

1. Fan-Section Construction: Direct-drive plenum type centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure and equipped with formed-steel channel base for integral mounting of fan, motor, and casing panels. Mount fan with vibration isolation.

2. Fan Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum rated fan speed and motor horsepower.

3. Vibration Control: Install fans on open-spring vibration isolators having a minimum of 1-inch static deflection and side snubbers or on a common base with the fan motor on a full width isolator support channel using 1” or 2” springs.

4. Fan-Section Source Quality Control: Sound Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal. Factory test fan performance for flow rate, pressure, power, air density, rotation speed, and efficiency. Establish ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

d. Motors

1. Noise Rating: Quiet.

2. Motors: Provide inverter duty, high-efficiency motors for variable-speed service.

e. Coils

1. Coil Sections: Common or individual, insulated, galvanized-steel casings for heating and cooling coils. Design and construct to facilitate removal and replacement of coil for maintenance and to ensure full airflow through coils.

2. Water Coils: Continuous circuit coil fabricated according to ARI 410. Coils shall be drainable. Pitch coils in unit casing for drainage. Provide with drain and vent plugs. Piping Connections: Threaded, on same end. Tubes: Copper. Fins: Aluminum. Fin and Tube Joint: Mechanical bond or silver brazed. Headers: Seamless copper tube with brazed joints, prime coated. Frames: Galvanized-steel channel frame, 0.064 inch. Baffles: Suitable to assure no air bypass around coils. Ratings: Design tested and rated according to ASHRAE 33 and ARI 410. Working-Pressure Ratings: 200 psig, 325ºF. Source Quality Control: Test to 300 psig and to 200 psig underwater.

f. Dampers

1. General: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpm face velocity through damper and 4-inch wg pressure differential.

2. Damper Operators: Electric specified in “HVAC Instrumentation and Controls”.

3. Economizer Section: Parallel-blade galvanized-steel dampers mechanically fastened to steel operating rod in reinforced, galvanized-steel cabinet. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously. Provide hinged access doors to view positioning of dampers.

g. Filter Section

1. Filters: Comply with NFPA 90A.

2. Filter Section: Provide filter holding frames arranged for flat or angular orientation, with hinged access doors on both sides of the unit. Filters shall be removable from one side. Filter media shall be 30% efficient and depth shall be 2”.

3. Disposable Panel Filters: Factory-fabricated, viscous-coated, flat-panel-type, disposable air filters with holding frames. Media: Interlaced glass fibers sprayed with nonflammable adhesive. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles. Duct-Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.

h. Subject to compliance with requirements, manufacturers offering modular air handling units that may be incorporated into the Work include, but are not limited to, the following:

1. Mainstream

2. Temtrol

2. Variable Frequency Drives

a. Provide VFDs as shown on the Drawings. Drive shall be sized to meet 125% of the full load current rating of the motor that it will control.

b. The variable frequency drives (VFDs) shall be manufactured by Asea Brown Boveri (ABB), designated ACH series, or a specifically approved equal.

c. The VFD manufacturer shall provide a start up service package for each VFD provided. Service shall include inspection, final adjustment, operational checks, and a final report for record purpose. Start up service shall be performed by a factory approved and certified technician.

d. To be included with start up service, for a period of 24 months after initial start up, not to exceed 30 months from date of manufacture, the VFD manufacturer shall include a full parts and labor on-site warranty at no additional costs.

e. Accessories to be furnished and mounted by the drive manufacturer and contained in a single enclosure. (The use of more than one enclosure is not acceptable).

1. Customer Interlock Terminal Strip - Provide a separate terminal strip for connection of fire, freeze contacts and external start command. All external interlocks and start/stop contacts shall function with drive in hand, auto or bypass.

2. Door interlocked disconnect, padlockable in off position.

3. Manual Transfer to line power via contactors and including class 20 bimetal motor thermal overload relays and fuse or circuit breaker protection while in bypass operation complete with manual bypass capability.

4. Service switch which provides the ability to service the controller (electronically isolated while in bypass operation) without having to remove power to motor.

3. In-line Circulator Pumps

a. Pumps shall be factory-assembled and -tested, horizontal, in-line, centrifugal, cast iron, oil lubricated booster pumps with mechanical seals. Specifically designed and guaranteed for quiet operation. Rated for 125 psig working pressure and 225°F continuous water temperature.

1. Casing Construction: Cast iron, with threaded companion flanges for piping connections smaller than 2-1/2", and threaded gage tappings at inlet and outlet connections.

2. Impeller Construction: Statically and dynamically balanced, closed, overhung, single-suction, conforming to ASTM B 584, and keyed to shaft.

3. Pump Shaft: Ground and polished carbon steel shaft with a hardened integral thrust collar. The shaft shall be supported by two horizontal sleeve bearings designed to circulate oil.

4. Mechanical Seal: Carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket.

5. Pump Bearings: Oil-lubricated, bronze, sleeve bearings.

6. Pump Coupling: Self-aligning, flexible coupling.

7. Motors: Non-overloading at any point on pump curve. Oil-lubricated, bronze, sleeve bearings. Drip-proof, quiet-operating, and rubber-mounted construction. Motors shall have built-in thermal overload protectors.

b. Subject to compliance with requirements, manufacturers offering circulating pumps that may be incorporated into the Work include, but are not limited to, the following:

1. Taco, Inc.

4. Water-to-Water Heat Pump Unit

a. Water-to-water heat pump unit shall be a factory assembled, water source unit capable of making warm water to supply the modular air handling unit reheat coils. The heat pump source loop shall be the chilled water return. The unit shall be capable of operating at 40ºF to 80ºF entering source-side water temperatures. The unit shall be capable of operating at 140ºF leaving hot-side water temperatures. Unit shall have sealed refrigerant circuits including a scroll compressor (with thermal overload protection), thermal expansion valve, two coaxial water-to-refrigerant heat exchangers (rated at 450 psig on the refrigerant side and 400 psig on the water side), high and low side access valves and safety controls

(including high and low refrigerant pressure switches) in each circuit. The source-side fluid circuit shall have a low fluid temperature (freezestat) safety switch. Controls shall include compressor contactor(s), compressor protection devices and a 24 volt transformer. Each compressor circuit shall have a lockout relay to disable compressor operation in the event of a trip of any of the safety switches. The lockout relay shall be reset from the main disconnect switch. Outer casing and internal support parts shall be fabricated from G-90 galvanized steel. Internal casing shall be insulated with 1" thick, 1½ lb multi-density, skin-coated fiberglass and unit shall have removable panels for access to the compressor and control box. Options to be factory installed by the manufacturer shall be as follows:

1. An alarm relay to provide a contact output on the trip of any safety switch.

2. A sound package to reduce radiated noise by addition of anti-vibration material and ¾", 1½ lb. insulation.

b. Subject to compliance with requirements, manufacturers offering water-to-water heat pump units that may be incorporated into the Work include, but are not limited to, the following:

1. Arctic Chill Inc.

5. Drycooler Unit

a. Drycooler unit shall be a factory assembled unit designed for outdoor installation and quiet operation. Provide cooler of forced-draft design with cooling core and fan mounted horizontally for vertical air intake and discharge. The unit shall be a Ref Plus, Model FVD, or specifically approved equal.

b. Provide core of seamless copper tubing mechanically-expanded to aluminum fins.

Maximum Operating Pressure: 250 PSIG

Maximum Operating Temperature: 300°F

c. Provide directly-driven fan with air-foil shaped, aluminum blades, and mounted in galvanized steel, venturi-shaped opening.

d. Provide self contained, ECM, variable speed motor

e. Provide galvanized steel supporting framework designed to withstand wind loads to 100 MPH and removable guards for core and fans made of zinc-plated or galvanized steel wire, complying with OSHA requirements.

f. Sound Level: Radiator shall have an overall sound pressure level not exceeding 51 dbA at 10 feet from the center line of the unit.

## I. HVAC INSTRUMENTATION AND CONTROLS

1. General Requirements:

a. The direct digital control system (DDCS) and integral controls for heating, ventilating, and air-conditioning (HVAC) equipment herein specified shall be fully integrated and installed as a complete package by the DDCS Contractor and shall be as manufactured by Automated Logic Corporation. This is an extension of an existing campus control system. The University vendor is Automated Logic, Inc., 29 North Plains Highway - #17, Wallingford, CT 06492, (203) 284-0100. The University contact for control systems is Mark Chadsey (860) 685-3804.

The DDCS shall include all computer software and hardware, input/output (I/O) devices, product integrated controls (PICs), field installed devices (FIDs), software option modules, automation sensors and controls, and associated wiring and piping. The DDCS Contractor shall interface all new controls with the

central OIS on Hamlin Street.

b. All automation equipment and HVAC equipment with integrated controls shall be supplied by one manufacturer.

c. The engineering, installation supervision and labor, calibration, software programming, and checkout necessary for a complete and fully operational DDCS as specified hereafter shall be provided by the DDCS Contractor.

d. The DDCS shall consist of all sensing devices, controllers, microprocessor-based PICs and FIDs, I/O devices, controlled devices and other accessory equipment including all control wiring as a complete and operable system.

e. The DDCS Contractor shall provide all necessary documentation and training as required to provide the Owner with a complete, operable control system.

f. Submit Diagrams: Separate piping and wiring diagrams for each system including electrical wiring, power sources through starters, motors and Hand-Off-Auto switches, locations of instruments, and the normal position of valves, dampers and relays. A detailed description of the operation of the control system, including control device designation, product numbers and descriptions shall accompany the drawings.

g. Submit DDCS shop drawings and data listed below, for approval prior to installation.

1. Controls including control diagrams, control panel layouts, descriptions of operation, and hardware materials listings.

2. Communications bus schematics showing PIC and FID panel layouts.

3. List of connected data points, including FID and PIC panels to which they are connected, and I/O devices.

4. Central work station personal computer (PC) configuration, complete with all peripheral devices, modems, etc., with interconnecting diagrams.

5. Technical specification data sheets of each system component.

6. Descriptive data and sequence of operation of all software, including complete operator's manual and custom programming.

h. Submit valve and damper actuator schedules (for supplied equipment).

i. Submit Complete DDCS documentation shall be provided prior to project completion. Provide shop drawings showing the as installed interconnection between control system devices and related connections to items provided by others. Provide sequences of operation and a complete I/O summary indicating input and output devices and their connection points.

j. Submit Operation and maintenance manuals.

2. Field Installed Sensors: Electronic sensors shall be vibration and corrosion resistant; for wall, immersion, or duct mounting as required.

a. Space temperature sensors shall be 5,000 or 10,000 ohm thermistors with wall plate adapter and blank cover assembly. The space temperature sensors shall be mounted approximately 60" above the floor.

b. Duct temperature sensors shall be 1000 ohm averaging RTDs, 5,000 or 10,000 ohm thermistors.

c. Water temperature sensors shall be well-mounted 5,000 or 10,000 ohm thermistors or 1000 ohm RTDs.

d. Static-Pressure Transmitter shall be nondirectional electronic sensor with suitable range for expected input, and temperature compensated. Accuracy shall be 2 percent of full scale with repeatability of 0.5 percent. Output 4 to 20 mA. For duct static pressure, range shall be 0 to 5 inches wg.

e. Status indication for fans and pumps shall be provided by a current sensing sensor. The sensor shall be installed at the motor starter or motor to provide load indication. The unit shall consist of a current transformer, a solid state current sensing circuit (with adjustable set point) and a solid state switch. A red light emitting diode (LED) shall indicate the on/off status of the unit. The switch shall provide a N.O. contact for wiring back to the FID.

f. Low temperature detection thermostat shall be provided to stop each air handling system as indicated and shall be of the manual reset type unless otherwise specified with sensing element not less than 20 feet long. Any one foot of sensing element, when subjected to temperatures below setpoint of controller, shall actuate thermostat switch mechanism regardless of temperature being sensed by the remainder of the element. The device shall have double-pole, double-throw contacts for fan shut down and remote alarming.

g. Space relative humidity sensors shall have a 0 to 100% RH range and be provided with wall plate adapter and blank cover. The sensors shall be electronic type. The measuring accuracy shall be 5% over the range. Space RH sensors shall be mounted with top 5' 6" above floor. Space RH sensors located in areas subject to physical damage shall be protected with heavy wire and guard assembly.

h. Carbon Dioxide Sensor and Transmitter: Single detectors using solid-state infrared sensors; suitable over a temperature range of 23 to 130ºF and calibrated for 0 to 2 percent, with continuous or averaged reading, 4- to 20-mA output. Reporting accuracy shall be plus or minus 50 ppm. Must be proportional-integral or proportional-integral-derivative, self-calibrating, carbon dioxide controller.

3. Control Valves: Factory-fabricated, electrically-actuated, fully modulating control valves. Except as otherwise indicated, provide valves of same size as connecting piping.

   a. Ball Valves: Class 125, cast iron or bronze body. Rated for operation at 125 psig and 250°F.

   b. Actuators: Provide UL-listed, normally-open, fully modulating, slow open/close, electric actuators. Operators shall close valves against pump shutoff head.

   c. Sizing: Sized for 3-psig maximum pressure drop at design flow rate.

   d. Flow Characteristics: Chilled water valves shall be two-way and have equal percentage characteristics. Reheat valves shall be three-way mixing valves.

   e. Manufacturers: Subject to compliance with requirements, manufacturers offering electrically-actuated control valves which may be incorporated in the work include, but are not limited to:

      Belimo
      Johnson Controls, Inc.
      Barber-Colman

4. Damper Actuators: Belimo electric. Size to operate with sufficient reserve power to provide full modulating action.

   a. Spring-Return Motors for Dampers Larger than 25 sq. ft.: Size for running and breakaway torque of 150 in lbf.

5. Sequence of Operation: The AHU shall operate in either occupied mode or unoccupied mode based on a seven day schedule and the status outputs of the zone occupancy sensors. Scheduled occupied mode shall be 7:00 AM to 9:00 PM M-F and 10:00 AM to 6:00 PM S-S. When all occupancy sensors indicate unoccupied for a period of 30 minutes, the AHU shall be indexed to unoccupied mode. At any time, if one or more occupancy sensors indicate occupied, the AHU shall be indexed to occupied. All schedules shall be fully adjustable

The chilled water coil and hot water coil of the air handling units are served by a two-pipe system. The DDC system shall monitor the chilled water coil supply temperature to determine whether chilled water or heating hot water is being supplied. This will determine whether the unit is in the cooling mode or heating mode and whether the cooling coil is active or the heating coil is active.

a. Run Conditions: The unit shall run whenever scheduled through the DDC system to operate.

| | |
|---|---|
| Occupied zone T, cooling: | 74 degF |
| Occupied zone RH, cooling: | 55 % |
| Occupied zone T, heating | 68 degF |
| Unoccupied zone T, cooling: | 75 degF |
| Unoccupied zone RH, cooling: | 55 % |
| Unoccupied zone T, heating | 60 degF |

b. Freeze Protection: If mixed air temperature is below 37ºF (adj.), the unit shall shut down and generate an alarm upon receiving a freezestat status.

c. AHU Optimal Start: The unit shall start prior to scheduled occupancy based on the time necessary for the zones to reach their occupied setpoint. The start time shall automatically adjusted based on changes in outside air temperature and zone temperatures.

d. 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:

1. Supply Fan Failure: Commanded on, but the status is off.

2. Supply Fan in Hand: Commanded off, but the status is on.

3. Supply Fan VFD Failure: Fault indication form VFD

e. Supply Air Volume Control: The speed of the Variable Frequency Drives will be adjusted manually or based upon a time schedule to allow the fan speed to be reduced during periods of unoccupancy or low occupancy.

f. Return Fan: The return fan shall run whenever the supply fan runs and the corresponding Variable Frequency Drive shall be automatically adjusted to maintain space static pressure conditions. Alarms shall be provided as follows:

1. Return Fan Failure: Commanded on, but the status is off.

2. Return Fan in Hand: Commanded off, but the status is on.

3. Return Fan VFD Failure: Fault indication form VFD

g. Return Fan Tracking: The return fan VFD shall modulate in unison with the supply air fan. The return fan VFD shall track the supply fan VFD at 90% (adj.) of the supply fan VFD speed. The return fan VFD speed shall not drop below 20% (adj.).

h. Supply and Return Air Volume Control: The speeds of the VFDs shall be modulated to allow the supply and return fan speeds to be reduced during periods of unoccupancy or low occupancy. The AHU fan speed shall be modulated to maintain a constant supply fan discharge static pressure.

i. Zone Volume Control: When the AHU is in the unoccupied mode the zone dampers will be positioned to provide a nominal 30% airflow to each of the three zones. When the AHU is in the occupied mode the zone dampers will be modulated to provide a nominal 50 % to 100% airflow to each of the three zones. In cooling mode the zone dampers shall modulate from 50% flow at 0.5 degF below setpoint to 100% flow at 1.5 degF above setpoint. In heating mode the zone dampers shall modulate from 50% flow at 1.5 degF

above setpoint to 100% flow at 0.5 degF below setpoint.

j. Supply Air Temperature Setpoint - Optimized: The controller shall monitor the supply air temperature and zone temperature(s). It shall maintain a supply air temperature setpoint reset based on cooling and heating requirements to maintain the zone temperature setpoints. The controller shall satisfy the zone with the greatest demand.

The supply air temperature setpoint shall be reset for cooling based on cooling requirements as follows:

1. The initial supply air temperature setpoint shall be 55°F (adj.).

2. As cooling demand increases, the setpoint shall incrementally reset down to a minimum of 53°F (adj.).

3. As cooling demand decreases, the setpoint shall incrementally reset up to a maximum of 65°F (adj.).

4. As the space relative humidity rises above 55% (adj), the supply air setpoint shall incrementally reset downwards to a minimum of 52°F (adj.).

If more heating (less cooling) is required, then the supply air temperature setpoint shall be reset for heating as follows:

5. The initial supply air temperature setpoint shall be 65°F (adj.).

6. As heating demand increases, the setpoint shall incrementally reset up to a maximum of 95°F (adj.).

7. As heating demand decreases, the setpoint shall incrementally reset down to a minimum of 72°F (adj.).

k. Cooling Mode: The controller shall monitor the supply air temperature and modulate the chilled water control valve to maintain the cooling and RH setpoints. The cooling shall be enabled whenever:

1. Outside air temperature is greater than 60°F (adj.).

2. AND the economizer is disabled or fully open.

3. AND the supply fan status is on.

4. AND the heating (HW) is not active.

Alarms shall be provided as follows:

5. High Supply Air Temp: If the supply air temperature is 5°F (adj.) greater than setpoint.

l. Heating Mode: The controller shall monitor the supply air temperature and modulate the chilled water control valve to maintain the heating setpoint. The heating shall be enabled whenever:

1. Outside air temperature is less than 60°F (adj.).

2. AND the supply fan status is on.

3. AND the cooling (if present) is not active.

The heating and cooling coil (open to 50%) valves shall open whenever:

1. Mixed air temperature drops from 45°F to 40°F (adj.).

2. OR the freezestat (if present) is on.

Alarms shall be provided as follows:

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

2. Low Supply Air Temp: If the supply air temperature is 5°F (adj.) less than setpoint.

m. Economizer: The controller shall monitor the mixed air temperature and modulate the economizer dampers in sequence to maintain a setpoint 2°F (adj.) less than the supply air temperature setpoint. The outside air dampers shall maintain a minimum adjustable position of 20% (adj.) open whenever occupied. The economizer shall be enabled whenever:

1. Outside air temperature is less than 60°F (adj.).

2. AND the outside air temperature is less than the return air temperature.

3. AND the supply fan status is on.

The economizer shall close whenever:

1. Mixed air temperature drops from 45°F to 40°F (adj.).

2. OR the freezestat (if present) is on.

3. OR on loss of supply fan status.

The outside and exhaust air dampers shall close and the return air damper shall open when the unit is off. If Optimal Start Up is available the mixed air dampers shall operate as described in the occupied mode except that the outside air damper shall modulate to fully closed during the heating season.

n. Minimum Outside Air Ventilation - Carbon Dioxide (CO2) Control: When in the occupied mode, the controller shall measure the outside air and return air CO2 levels and modulate the outside air damper open on rising CO2 concentrations, overriding normal damper operation to maintain a 500 ppm (adj.) inside/outside CO2 differential. A minimum outdoor air intake (base ventilation rate) of 30% of the design ventilation rate should be provided during occupied periods regardless of CO2 concentration to account for non-occupant related contaminant sources. When the unit is in unoccupied mode the OA and EX dampers shall be closed and the RA shall be open unless OA is needed for RH control. Alarms shall be provided as follows:

1. High Return Air Carbon Dioxide Concentration: If the return air CO2 concentration is greater than 1000 ppm (adj.).

o. Dehumidification Mode: During the cooling mode, the controller shall continuously monitor the space relative humidity. When the RH rises above 52%(adj) the controller shall reset the SAT setpoint downwards to increase the amount of dehumidification. When the RH rises above 53%(adj), it shall start the water-to-water heat pump and two circulator pumps to supply supplemental ChW. It shall modulate the chilled water control valve to maintain relative humidity at its setpoint (55%) and shall modulate the three zone reheat control valves to maintain the respective zone space temperature setpoints. The heat pump shall provide a constant 120 degF RHWS T. The DCS shall modulate the heat pump three way heat source control valve on the cold side of the heat pump to maintain the leaving water temperature at 44 degF.

p. Swing Season Cooling Mode: During the heating mode, when the OAT rises above 55 degF (adj), the controller shall monitor the space temperature and relative humidity. If the RH rises above its setpoint of 55% (adj.), it shall index the HW and ChW isolation valves, putting the AHU into cooling mode, and start the water-to-water heat pump and two circulator pumps to produce ChW. It shall modulate the chilled water control valve to maintain relative humidity at its setpoint and shall modulate the three zone reheat control valves to maintain the respective zone space temperature setpoints. The heat pump shall provide a constant 45 degF ChWS T. The DCS shall modulate the heat pump three-way heat rejection control valve on the hot side of the heat pump to maintain the leaving water temperature at 120 degF. As the RHW loop temperature begins to exceed 130 degF, a three way valve will send hot eater to the external drycooler. The

controller shall modulate the drycooler fan to reject excess heat to atmosphere and maintain the RHWRT to the heat pump at or below 120 degF.

q. Filter Differential Pressure Monitor: The controller shall monitor the differential pressure across the filter. Alarms shall be provided as follows:

   1. Filter Change Required: Filter differential pressure exceeds a user definable limit (adj.).

r. Mixed Air Temperature: The controller shall monitor the mixed air temperature and use as required for economizer control. Alarms shall be provided as follows:

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

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

s. Return Air Temperature: The controller shall monitor the return air temperature and use as required for setpoint control or economizer control (if present). Alarms shall be provided as follows:

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

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

t. Supply Air Temperature: The controller shall monitor the supply air temperature. Alarms shall be provided as follows:

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

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

u. Operator Station Display: Indicate the following on operator workstation display terminal:

   1. DDC system graphic.
   2. DDC system on-off indication.
   3. DDC system occupied/unoccupied mode.
   4. Outdoor air temperature indication.
   5. Outdoor air CO2 indication.
   6. Supply fan on-off indication.
   7. Supply fan speed.
   8. Supply fan VFD fault indication.
   9. Return fan on-off indication.
   10. Return fan speed.
   11. Return fan VFD fault indication.
   12. Mixed air temperature indication.
   13. Mixed air temperature set point.
   14. Mixed air damper position.
   15. Zone(s) temperature indication.
   16. Zone(s) temperature set point.
   17. Zone(s ) air CO2 indication.
   18. Space relative humidity indication.
   19. Space relative humidity set point.
   20. Filter air pressure drop indication.
   21. Filter high air pressure set point.
   22. Supply air temperature indication.
   23. Supply air temperature set point.
   24. Chilled water coil control valve position.
   25. Chilled water coil supply water temperature indication.
   26. Reheat coils - control valve position.
   27. H/C water supply temperature

28. H/C water return temperature
29. Heat pump hot side outlet temperature
30. Drycooler hot side inlet temperature
31. Heat pump hot side inlet temperature
31. Heat pump cold side outlet temperature
32. Heat pump cold side inlet temperature
33. Heat pump on/off

v. Fan coil units: The FCU's shall have a motorized, pressure independent ball valve to control the flow of ChW/HW to the respective heating/cooling coil. The valve shall be opened/closed by a programmable thermostat/sensor to maintain the zone T at occupied/unoccupied setpoint. In cooling mode, an increase in zone T shall open the valve; in heating mode, an increase in zone T shall close the valve. In the occupied mode, the DCS shall control at 68h/72c deg F (adj). In the unoccupied mode, the DCS shall control at 66h/74c deg F (adj).

J. IDENTIFYING DEVICES AND LABELS

1. General: Manufacturer's standard products of categories and types required for each application. If more than one type is specified for application, selection is Installer's option, but provide one selection for each product category.

2. Pressure-Sensitive Pipe Markers: Manufacturer's standard preprinted, permanent adhesive, color-coded, pressure-sensitive vinyl, complying with ASME A13.1. Pipe markers shall:

   a. Identify the fluid inside each pipe.

   b. Indicate the direction of flow of the fluid inside each pipe.

3. Plastic Valve Tags: Manufacturer's standard solid plastic valve tags with printed enamel lettering, with piping system abbreviation in approximately 3/16" high letters and sequenced valve numbers approximately 3/8" high, and with 5/32" hole for fastener.

   a. Size, shape and color combination as specified or scheduled for each piping system.

4. Valve Tag Fasteners: Manufacturer's standard solid brass chain (wire link or beaded type), or solid brass S-hooks of the sizes required for proper attachment of tags to valves, and manufactured specifically for that purpose.

5. Valve Schedule Frames: For each page of the valve schedule, provide a glazed display frame, with screws for removable mounting on walls.

K. MISCELLANEOUS

The Contractor shall furnish and install all the appropriate items required to complete the installation of the equipment specified above. These items include, but are not limited to, chilled water, heating hot water, and drain piping, fasteners and mounting hardware. The Contractor shall be responsible for all cutting, patching, repainting and reinsulating.

## III. INSTALLATION

A. GENERAL

1. The Contractor shall visit site with plans and specifications in hand and shall become fully familiar with all aspects and intentions of work to be performed before submitting price.

2. The Contractor shall verify existing field conditions and tie-in points prior to start of work. Do not proceed

with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3. The Contractor shall perform the installation of the equipment specified above in strict accordance with accepted industry standards and manufacturer's recommendations.

4. Since the facility and surrounding campus buildings will be occupied while work is in progress, the Contractor must schedule and perform the work in such a way that the disruption of the normal activities which take place there is minimized. Clean-up activities must be done on a daily basis to avoid occupant inconvenience as much as possible.

5. All work shall be installed in strict accordance with all state and local codes. This Contractor shall obtain and pay for all permits and certificates required by local and state authorities and/or governing bodies having jurisdiction over his work.

6. The Contractor shall replace or repair at his own expense any part of the work, performed or furnished which proves defective in workmanship or material within a one (1) year period after project has been accepted by Owner.

7. All piping shall be flushed out and pressure-tested to ensure tightness.

8. After all equipment is installed and tested, it shall be run through functional tests to the satisfaction of the Owner and Engineer.

B. ELECTRICAL

1. Contractor shall be responsible for all removals and relocations of existing electrical devices, conduits, conductors, junction boxes, fixtures, fire detection/alarm sensors, and data/sound system wiring and devices.

2. Contractor shall be responsible for all power and control wiring, transformers, relays, circuit breakers, disconnects, power panel, etc. as required under this contract.

3. Provide new power wiring, motor branch circuit wiring to all new motors and loads, all control wiring and extend new conduit as required.

3. Provide new wiring and conduit to relocated devices as required.

4. All work shall be done in compliance with the National Electrical Code and the Connecticut Building Code.

5. Ground equipment.

6. All wiring shall be run in EMT.

7. All final connections to equipment shall be made with “sealtight” flexible metallic conduit.

C. EQUIPMENT LOCATIONS

The equipment shall be located as indicated on the drawings.

D. PIPING INSTALLATION

1. General Locations and Arrangements: Drawings indicate the general location and arrangement of the piping systems. Location and arrangement of piping layout take into consideration pipe sizing and friction loss, expansion, pump sizing, and other design considerations. So far as practical, install piping as indicated.

2. Install components with pressure rating equal to or greater than system operating pressure.

3. Use fittings for all changes in direction and all branch connections.

4. Install couplings according to the manufacturer's printed instructions.

5. Install exposed piping at right angles or parallel to building walls. Diagonal runs are not permitted, unless expressly indicated.

6. Install piping free of sags or bends and with ample space between piping to permit proper insulation applications.

7. Install piping tight to slabs, beams, joists, columns, walls, and other permanent elements of the building. Provide space to permit insulation applications, with 1" clearance outside the insulation.

8. Locate groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

9. Install drains at low points in mains, risers, and branch lines consisting of a tee fitting, 3/4" ball valve, and short 3/4" threaded nipple and cap.

10. Hydronic Piping:

    a. Install piping at a uniform grade of 1" in 40' upward in the direction of flow.

    b. Reduce pipe sizes using eccentric reducer fitting installed with level side up. Locate reducers at least 18" min. distance from branch connection.

    c. Install branch connections to mains using tee fittings in main pipe, with the takeoff coming out the bottom of the main pipe. For up-feed risers, install the takeoff coming out the top of the main pipe.

    d. Install hose bibs on exposed piping where indicated with vacuum breaker.

11. Install sleeves for pipes passing through concrete and masonry walls, concrete floor and roof slabs.

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

        1. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2" above finished floor level.

    b. Build sleeves into new walls and slabs as work progresses.

    c. Install sleeves large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation. Use the following sleeve materials:

        1. Steel Pipe Sleeves: For pipes smaller than 6-inch NPS.

12. Fire Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestopping sealant materials.

13. Install unions in pipes sizes 2" and smaller, adjacent to each valve, at final connections to each piece of equipment, and elsewhere as indicated. Unions are not required on flanged devices.

14. Install flanges on valves, apparatus, and equipment having 2-1/2" and larger connections.

15. Verify final equipment locations for roughing-in with field measurements and with the requirements of the actual equipment.

16. Anchor piping for proper direction of expansion and contraction.

E. PIPE JOINT CONSTRUCTION

1. Welded Joints: Comply with the requirements of ASME Code B31.9 - "Building Services Piping".

2. Threaded Joints: Conform to ANSI B1.20.1, tapered pipe threads for field cut threads. Join pipe, fittings, and valves as follows:

   a. Note the internal length of threads in fittings or valve ends, and proximity of internal seat or wall, to determine how far pipe should be threaded into joint.

   b. Align threads at point of assembly.

   c. Apply appropriate tape or thread compound to the external pipe threads (except where dry seal threading is specified).

   d. Assemble joint to appropriate thread depth. When using a wrench on valves, place the wrench on the valve end into which the pipe is being threaded.

   e. Damaged Threads: Do not use pipe with threads which are corroded or damaged. If a weld opens during cutting or threading operations, that portion of pipe shall not be used.

3. Flanged Joints: Align flange surfaces parallel. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets as flat and parallel as possible. Use suitable lubricants on bolt threads. Using a torque wrench, tighten bolts gradually and uniformly, not exceeding the maximum torque specified by the bolt manufacturer.

4. Plastic Piping Joint Construction: Join plastic pipe and fittings as follows:

   a. Ream ends of pipes and tubes and remove burrs.

   b. Remove scale, slag, dirt, and debris from both inside and outside of pipe and fittings before assembly.

   c. Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join pipe and fittings according to the following:

      1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.

      2. PVC Nonpressure Piping: ASTM D 2855.

F. HANGERS AND SUPPORTS

1. Horizontal-Piping Hangers and Supports: Except as otherwise indicated, provide factory-fabricated horizontal-piping hangers and supports complying with ANSI/MSS SP-58, of one of the following MSS types listed, selected by Installer to suit horizontal-piping systems, in accordance with MSS SP-69 and manufacturer's published product information. Use only one type by one manufacturer for each piping service. Select size of hangers and supports to exactly fit pipe size for bare piping, and to exactly fit around piping insulation with saddle or shield for insulated piping. Provide copper-plated hangers and supports for copper piping systems.

   a. Adjustable Steel Clevis Hangers (MSS Type 1) (2" and over): For suspension of noninsulated or insulated stationary pipes, NPS 1/2 to NPS 30.

   b. Single Pipe Rolls (MSS Type 41): For suspension of pipes, NPS 1 to NPS 30, from two rods if longitudinal movement caused by expansion and contraction might occur.

2. Hanger-Rod Attachments: Except as otherwise indicated, provide factory-fabricated hanger-rod attachments complying with ANSI/MSS SP-58, of one of the following MSS types listed, selected by Installer to suit horizontal-piping hangers and building attachments, in accordance with MSS SP-69 and manufacturer's published product information. Use only one type by one manufacturer for each piping service. Select size of hanger-rod attachments to suit hanger rods. Provide copper-plated hanger-rod attachments for copper-piping systems.

a. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.

b. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.

3. Building Attachments: Except as otherwise indicated, provide factory-fabricated building attachments complying with ANSI/MSS SP-58, of one of the following MSS types listed, selected by Installer to suit building substrate conditions, in accordance with MSS SP-69 and manufacturer's published product information. Select size of building attachments to suit hanger rods. Provide copper-plated building attachments for copper-piping systems.

   a. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.

   b. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.

   c. C-Clamps (MSS Type 23): For structural shapes.

   d. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.

   e. Malleable Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.

   f. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:

      Light Duty (MSS Type 31): 750 lb
      Medium Duty (MSS Type 32): 1500 lb
      Heavy Duty (MSS Type 33): 3000 lb

4. Saddles and Shields: Except as otherwise indicated, provide saddles or shields under piping hangers and supports, factory-fabricated, for all insulated piping. Size saddles and shields for exact fit to mate with pipe insulation. All lines 2-1/2" and over shall have protection saddles.

   a. Steel Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.

   b. Protection Shields (MSS Type 40): Of length recommended by manufacturer to prevent crushing of insulation.

   c. Thermal-Hanger Shield Inserts: For supporting insulated pipe, 360-degree insert of high-density, 100 psi minimum compressive strength, cellular-glass pipe insulation, same thickness as adjoining insulation with vapor barrier and encased in 360-degree sheet metal shield.

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

   a. Install the following pipe attachments:

      1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.

      2. Pipe Roller: Manufacturers' Standardization Society of the Valve and Fittings Industry MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.

   b. Install hangers with the following minimum rod sizes and maximum spacings:

| Nom. Pipe | Steel Pipe | Copper Tube | Min. Rod |
|---|---|---|---|

| Size - In. | Max. Span - Ft. | Max. Span - Ft. | Diam. - In. |
|---|---|---|---|
| Up to 3/4 | 7 | 5 | 3/8 |
| 1 | 7 | 6 | 3/8 |
| 1-1/4 | 7 | 5 | 3/8 |
| 1-1/2 | 9 | 8 | 3/8 |
| 2 | 10 | 8 | 3/8 |
| 2-1/2 | 11 | 9 | 1/2 |
| 3 | 12 | 10 | 1/2 |
| 3-1/2 | 13 | 11 | 1/2 |
| 4 | 14 | 12 | 5/8 (1/2 for copper) |
| 5 | 16 | 13 | 5/8 (1/2 for copper) |
| 6 | 17 | 14 | 3/4 (5/8 for copper) |

c. Support vertical runs at each floor.

d. All hangers shall be sized to fit outside of pipe insulation. Provide insulation shields at all hangers.

G. VALVE APPLICATIONS

1. General Duty Valve Applications: The Drawings indicate valve types to be used. Where specific valve types are not indicated, the following shall apply:

   a. Shut-off duty: Use ball valves.

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

3. Install valves and unions for each fixture and item of equipment arranged to allow equipment removal without system shutdown. Unions are not required on flanged devices.

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

5. Install valves in a position to allow full stem movement.

6. Install drain valves at low points in mains, risers, branch lines, and elsewhere as required for system drainage.

7. Install check valves on pump discharge where indicated and elsewhere as required to control flow direction.

8. Installation of check valves: Install for proper direction of flow as follows:

   a. Swing check valves: Horizontal position with hinge pin level.

9. Install calibrated balancing valves where indicated on drawings.

H. PIPING SPECIALTIES INSTALLATIONS

1. Install strainer with blow-off connection upstream of each control valve, in-line pump, and elsewhere as indicated. Install ¾" nipple and ball valve in blowdown connection of strainers 2" and larger. Match size of strainer blowoff connection for strainers smaller than 2".

2. Install diaphragm-type expansion tank where indicated. Vent and purge air from hydronic system. Charge tank with proper air charge to suit system design requirements.

3. Install manual air vents at high points in the system, at heat transfer coils, and elsewhere as required for system air venting.

I. INSTALLATION OF METERS AND GAGES

1. General: Install meters and gages in accordance with manufacturer's written instructions, and, in so far as possible, in locations indicated. Install meters and gages in locations and with orientations which will make them easy to read.

2. Thermometers: Install thermometers in vertical orientation. Adjust tilt to facilitate reading by an observer standing on the floor.

    a. Locations: Install at locations indicated on plans.

    b. Thermometer Wells: Install in piping tee where thermometers are indicated, in vertical orientation. Fill well with oil or graphite and secure cap.

3. Install pressure gages in piping tee with gage valve, located on pipe at most readable position.

    a. Locations: Install at locations indicated on plans.

    b. Gage Valves: Install needle type valve in piping tee with snubber.

4. Connections: Install meters and gages adjacent to machines and equipment to allow service and maintenance.

5. Adjusting and cleaning: Calibrate meters according to manufacturer's written instructions, after installation. Adjust faces of meters and gages to proper angle for best visibility. Clean windows of meters and gages and factory-finished surfaces. Replace cracked and broken windows, and repair scratched and marred surfaces with manufacturer's touch-up paint.

J. DUCT AND ACCESSORIES INSTALLATION

1. Duct Installation: Construct and install each duct system for the specific duct pressure classification indicated.

    a. Install ducts with the smallest possible number of joints.

    b. Use fabricated fittings for all changes in direction, changes in size and shape, and for all connections.

    c. Install couplings tight to duct wall surface, with projections into duct at connections kept to a minimum.

    d. Orient ducts, except as otherwise indicated, vertically and horizontally, parallel and perpendicular to building lines; avoid diagonal runs. Install duct systems in shortest route that does not obstruct usable space or block access for servicing building and its equipment.

    e. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

    f. Install insulated ducts with 1" clearance outside of insulation.

    g. Non-Fire-Rated Partition Penetrations: Where ducts pass through interior partitions and exterior walls, and are exposed to view, conceal space between construction opening and duct or duct insulation with sheet metal flanges of same gage as duct. Overlap opening on all sides by at least 1-1/2".

2. Seam and Joint Sealing:

    a. Pressure Classification Greater Than 3" Water Gage: Seal all transverse joints, longitudinal seams, and duct penetrations.

    b. Pressure Classification between 2" and 3" Water Gage: Seal all transverse joints and longitudinal seams.

    c. Pressure Classification Less Than 2" Water Gage: Seal transverse joints only.

    d. Seal externally-insulated ducts prior to insulation installation.

3. Hanging and Supporting:

   a. Install rectangular metal ducts with support systems indicated in SMACNA "HVAC Duct Construction Standards", Tables 4-1 through 4-3, and Figures 4-1 through 4-8.

   b. Support horizontal ducts within 2 feet of each elbow and within 4 feet of each branch intersection.

   c. Support vertical ducts at a maximum interval of 16 feet and at each floor.

   d. Upper attachments to structures shall have an allowable load not exceeding 1/4 of the failure (proof test) load but are not limited to the specific methods indicated.

4. Connections:

   a. Equipment Connections: Use flexible connectors to connect ductwork to equipment mounted on vibration isolators and/or equipment containing rotating machinery.

   b. Branch Connections: Comply with SMACNA "HVAC Duct Construction Standards", Figures 2-7 and 2-8.

   c. Inlet and Outlet Connections: Comply with SMACNA "HVAC Duct Construction Standards", Figures 2-16 through 2-18.

   d. Terminal Unit Connections: Comply with SMACNA "HVAC Duct Construction Standards", Figure 2-19.

   e. Remake leaking joints as required.

6. Install duct accessories in accordance with manufacturer's installation instructions and with applicable portions of SMACNA's "HVAC Duct Construction Standards, Metal and Flexible", and with recognized industry practices to ensure that products serve intended function.

7. Install duct silencers rigidly to ducts.

8. Install volume control dampers in lined ducts using methods which avoid erosion and other damage to the liner.

9. Install duct access doors to open against system air pressure, with latches operable from outside or inside, except outside only where duct is too small for person to enter.

10. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

    a. On both sides of duct coils.

    b. Downstream from manual volume dampers.

    c. Adjacent to and close enough to fire dampers, to reset or reinstall fusible links. Access doors for access to fire dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.

11. Install flexible connectors immediately adjacent to equipment in ducts associated with fans and motorized equipment supported by vibration isolators.

12. Install fire dampers according to the manufacturer's UL-approved printed instructions.

13. Install fusible links in fire dampers.

14. Adjust volume control devices as required to achieve required air flow. Vacuum clean duct systems prior to

final acceptance to remove dust and debris.

15. Adjust duct accessories for proper settings.

16. Adjust fire dampers for proper action.

K. PIPING INSULATION INSTALLATION

1. Insulate all new piping as indicated. Insulate all new piping/valving work and modified sections of existing piping.

2. Repair new sections of insulation that are damaged during installation and start-up.

3. Omit insulation on unions, flanges, strainers, flexible connections, and expansion joints.

4. Install insulation products in accordance with manufacturer's written instructions, and in accordance with recognized industry practices to ensure that insulation serves its intended purpose.

5. Install insulation materials with smooth and even surfaces. Insulate each continuous run of piping with full-length units of insulation, with single cut pieces to complete run. Do not use cut pieces or scraps abutting each other.

6. Clean and dry pipe surfaces prior to insulating. Butt insulation joints firmly together to ensure complete and tight fit over surfaces to be covered.

7. Maintain integrity of vapor-barrier jackets on pipe insulation, and protect to prevent puncture or other damage.

8. Cover valves, fittings and similar items in each piping system with equivalent thickness and composition of insulation as applied to adjoining pipe run. Install factory molded units.

9. Butt pipe insulation against pipe hanger insulation inserts. Apply 3" wide vapor barrier tape or band over the butt joints.

10. Exterior Wall Penetrations: For penetrations of below grade exterior walls, terminate insulation flush with mechanical sleeve seal. Seal terminations with vapor barrier coating.

11. Hangers and Supports: Apply insulation continuously through hangers and around support attachments. Cover hanger inserts and shields with jacket material matching adjacent pipe insulation.

12. Apply insulation with a minimum number of joints.

13. Stagger joints on double layers of insulation.

14. Seal exposed ends with lagging adhesive.

15. Insulation inserts at all hangers shall be cellular glass.

16. Fire-Rated Wall and Partition Penetrations: Terminate insulation at penetrations through fire-rated walls and partitions. Seal insulation ends with vapor barrier coating. Seal around penetration with fire-stopping or fire-resistant joint sealer.

17. Apply insulation with integral jackets as follows:

    a. Pull jacket tight and smooth.

    b. Cover circumferential joints with butt strips at least 3" wide, and of same material as insulation jacket. Secure with adhesive and outward clinching staples along both edges of butt strip and space 4" on center.

c. Longitudinal Seams: Overlap seams at least 1-1/2". Apply insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 4" on center.

d. Vapor Barrier Coatings: Where vapor barriers are indicated, apply on seams and joints, over staples, and at ends butt to flanges, unions, valves, and fittings.

e. At penetrations in jackets for thermometers and pressure gages, fill and seal voids with vapor barrier coating.

f. Repair damaged insulation jackets, except metal jackets, by applying jacket material around damaged jacket. Adhere, staple, and seal. Extend patch at least 2" in both directions beyond damaged insulation jacket and around the entire circumference of the pipe.

18. Install/maintain a continuous vapor barrier on all chilled water pipes.

L. EXISTING INSULATION REPAIR

1. Repair damaged sections of existing mechanical insulation at all interface points. Use insulation of same thickness as existing insulation, and install all-service jacket lapped and sealed over existing.

M. PROTECTION AND REPLACEMENT

1. Replace damaged insulation which cannot be repaired satisfactorily, including units with vapor barrier damage and moisture saturated units.

2. Insulation Installer shall advise Contractor of required protection for insulation work during remainder of construction period, to avoid damage and deterioration.

N. MODULAR AIR HANDLING UNITS INSTALLATION

1. Install modular indoor air handling unit on existing concrete floor on neoprene vibration isolator pads.

2. Arrange installation of units to provide access space around modular indoor air handling units for service and maintenance.

3. Piping installation requirements are specified elsewhere. Drawings indicate general arrangement of piping, fittings, and specialties.

4. Install piping adjacent to machine to allow service and maintenance.

5. Connect condensate drain pans using NPS 1-1/4, PVC plastic piping. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

6. Heating Hot Water and Chilled Water Piping: Connect to supply and return coil tappings with shutoff or balancing valve and union or flange at each connection.

7. Duct installation and connection requirements: Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connections.

8. Electrical: Comply with applicable NEC requirements for power wiring, switches, and motor controls.

9. Ground equipment per NEC requirements.

10. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

11. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect field-assembled

components and equipment installation, including piping and electrical connections. Report results in writing.

a. Leak Test: After installation, fill water coils with water and test coils and connections for leaks. Repair leaks and retest until no leaks exist.

b. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.

c. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

12. Engage a factory-authorized service representative to perform startup service.

13. Final Checks before Startup: Perform the following:

a. Verify that shipping, blocking, and bracing are removed.

b. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.

c. Perform cleaning and adjusting specified in this section.

d. Disconnect fan drive from motor, verify proper motor rotation direction, and verify free fan wheel rotation and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.

e. Lubricate bearings, pulleys, belts, and other moving parts with factory-recommended lubricants.

f. Set outside and return air mixing dampers to minimum outside air setting.

g. Comb coil fins for parallel orientation.

h. Install clean filters.

i. Verify that manual and automatic volume control and fire dampers in connected duct systems are in fully open position.

14. Starting procedures for modular indoor air handling units include the following:

a. Measure and record motor electrical values for voltage and amperage.

b. Manually operate dampers from fully closed to fully open position and record fan performance.

15. Cleaning:

a. Clean modular indoor air handling units internally, on completion of installation, according to manufacturer's written instructions. Clean fan interiors to remove foreign material and construction dirt and dust. Vacuum clean fan wheels, cabinets, and coils entering air face.

b. After completing system installation and testing, adjusting, and balancing modular indoor air handling and air-distribution systems, clean filter housings and install new filters.

16. Engage a factory-authorized service representative to train Owner's maintenance personnel in the procedures and schedules related to start-up, adjust, operate, and shut-down, troubleshooting, servicing, preventative maintenance, and how to obtain replacement parts. Schedule training with at least 7 days advance notice.

O. VARIABLE FREQUENCY DRIVE

1. Install VFD as indicated, in accordance with manufacturer's written instructions, applicable requirements of NEC, NEMA standards, and NECA's "Standard of Installation", and in compliance with recognized industry practices to ensure that products fulfill requirements.

    a. Coordinate with other work including motor and electrical wiring/cabling work, as necessary to interface installation of VFD with other work.

    b. VFD installation shall be the responsibility of the Contractor.

2. All testing and start-up shall be performed by the VFD factory representative. Subsequent to wire cable hook-up, energize VFD and demonstrate functioning of equipment in accordance with requirements; where necessary, correct malfunctioning units. Prior to start-up testing, the Contractor shall provide the Owner and Engineer a start-up sequence check list to assist in verification of the system operation. After the field installation is completed, the Contractor shall conduct with the Engineer, Owner and other related trades operational tests of the complete system. Start-up testing shall include operation of the complete system to ensure that all systems operate satisfactorily including any process signal speed control interfaces. Drive supplier shall provide all required programming terminals, power supplies, meters and appropriate signal generators to test, calibrate and start-up the entire system.

P. HVAC INSTRUMENTATION AND CONTROLS

1. Examine areas and conditions under which automatic control components are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in a manner acceptable to Installer.

2. Install systems and materials in accordance with manufacturer's instructions and contract drawings. The term "control wiring" is defined to include wire in conduit and miscellaneous materials as required for mounting and connecting automatic control devices. Install complete control wiring system for automatic controls. Conceal wiring, except in mechanical rooms and areas where other conduit and piping are exposed. Provide multi-conductor instrument harness (bundle) in place of single conductors where number of conductors can be run along common path in conduit. Wiring shall be color coded.

3. Following set up, adjustment and calibration of automatic controls, demonstrate satisfactory performance of systems to Engineer and Owner. Provide 4 copies of operations manuals to Owner, indicating final components configuration and calibration settings of instrumentation. Include specification sheets and drawings of final schematic layout, maintenance requirements and other pertinent information required for Owner to maintain system following expiration of 1 year system warranty. Warranty period shall begin from time of acceptance of system by Owner.

4. Provide control software changes/adjustments when needed during the first 12 months of operation of the entire hot water system.

Q. LABELING AND IDENTIFYING

1. Piping Systems: Install pipe markers on each system. Include arrows showing normal direction of flow.

    a. Locate pipe markers as follows if piping is exposed in finished spaces, machine rooms, and accessible maintenance spaces, such as shafts, tunnels, plenums, and exterior nonconcealed locations:

        1. Near each valve and control device.

        2. Near each branch, excluding short takeoffs for fixtures and terminal units. Mark each pipe at branch, if flow pattern is not obvious.

        3. Near locations if pipes pass through walls, floors, ceilings, or enter nonaccessible enclosures.

        4. At access doors, manholes, and similar access points that permit view of concealed piping.

        5. Near major equipment items and other points of origination and termination.

6. Spaced at a maximum distance of 25-foot intervals along each run.

2. Adjusting: Relocate identifying devices as necessary for unobstructed view in finished construction.

R. FIELD QUALITY CONTROL

1. Preparation for Testing: Prepare piping in accordance with ASME B 31.9 and as follows:

   a. Leave joints including welds uninsulated and exposed for examination during the test.

   b. Provide temporary restraints for expansion joints which cannot sustain the reactions due to test pressure. If temporary restraints are not practical, isolate expansion joints from testing.

   c. Flush system with clean water. Clean strainers.

   d. Isolate equipment that is not to be subjected to the test pressure from piping. If a valve is used to isolate the equipment, its closure shall be capable of sealing against the test pressure without damage to the valve. Flanged joints at which blinds are inserted to isolate equipment need not be tested.

   e. Install relief valve set at a pressure no more than 1/3 higher than the test pressure, to protect against damage by expansion of liquid or other source of overpressure during the test.

2. Testing: Test piping as follows:

   a. Use ambient temperature water as the testing medium, except where there is a risk of damage due to freezing. Another liquid may be used if it is safe for workmen and compatible with the piping system components.

   b. Hydronic piping: Use vents installed at high points in the system to release trapped air while filling the system. Use drains installed at low points for complete removal of the liquid.

   c. Examine system to see that equipment and parts that cannot withstand test pressures are properly isolated. Examine test equipment to ensure that it is tight and that low pressure filling lines are disconnected.

   d. Subject piping system to a hydrostatic test pressure which at every point in the system is not less than 1.5 times the design pressure. The test pressure shall not exceed the maximum pressure for any vessel, pump, valve, or other component in the system under test. Make a check to verify that the stress due to pressure at the bottom of vertical runs does not exceed either 90% of specified minimum yield strength, or 1.7 times the "SE" value on Appendix A of ASME B31.9.

   e. After hydrostatic test pressure has been applied for at least 4 hours, examine the system for leakage. Eliminate leaks by tightening, repairing, or replacing components as appropriate, and repeat hydrostatic test until there are no leaks. Record test pressure at 1/2 hour intervals for the duration of the test.

S. PAINTING AND FINISHING

1. Do not paint piping specialties with factory-applied finish.

2. Damage and Touch-Up: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

T. ADJUSTING AND CLEANING

1. Clean and flush hydronic piping systems. Remove and replace temporary strainer screens.

2. Chemical Treatment: Provide a water analysis prepared by the chemical treatment supplier to determine the type and level of chemicals required to prevent scale and corrosion in each hydronic system. Perform initial

treatment after completion of system testing.

U. COMMISSIONING

1. Fill and vent each hydronic system and perform initial chemical treatment.
2. Check expansion tanks to determine that they are not air bound and that the system is completely full of water.
3. Before operating the hydronic systems, perform the following steps:
   a. Open valves to their full open positions. Close equipment bypass valves.
   b. Remove and clean strainers.
   c. Check pumps for proper direction of rotation. Correct improper wiring.
   d. Set automatic fill valves for the required system level pressure.
   e. Set temperature controls so that they are calling for full flow.
   f. Check and set operating temperatures to design requirements.
   g. Lubricate motors and bearings.

## IV. SHOP DRAWINGS & SUBMITTALS

Contractor shall submit to Engineer four (4) copies of shop drawings of equipment listed below. The Contractor's intent to use the exact names specified does not relieve him of the responsibility of submitting.

a. Pipe hangers
b. Valves
c. Strainers
d. Meters and gages
e. Flexible connectors
f. Duct silencers
g. Piping insulation
h. Duct liner
i. Fire dampers
j. Volume dampers
k. Modular air handling units
l. Variable frequency drives
m. Controls
n. Circuit breakers
o. Motor starters

## V. FUNCTIONAL TEST

As soon as the work is complete and start-up has been performed, the Contractor will conduct a functional test of all the equipment installed. At this test, the Contractor will demonstrate to the Engineer and the Owner that all components installed perform as specified.