SECTION 23 01 00 - GENERAL PROVISIONS OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Provide all labor, materials, tools, and services for a complete installation of equipment and systems contained in contract documents.

B. Principal features of work included are:

1. Heating, ventilating, and air-conditioning system.
2. Control system including line and low voltage control wiring and conduit.
3. Demolition of existing equipment, ductwork, and piping.

1.2 RELATED WORK

A. Electrical power and interlock and control wiring and conduit.

1.3 GENERAL

A. The contract documents form a guide for a complete system. Provide all items necessary to provide a complete system but not specifically mentioned, such as hangers, transitions, offsets, and drains.

B. Layouts indicated on drawings are diagrammatical only. Coordinate exact location of equipment and piping to eliminate conflict with other divisions. Designer reserves right to make reasonable changes in location of equipment, ductwork, and piping prior to construction. Coordination drawings shall be submitted prior to any equipment/systems being installed to ensure that installation conflicts between trades are minimized.

C. Should Contractor find during progress of work that in his judgment existing conditions make desirable a modification, report such item promptly to Designer for instructions. Do not make deviations from contract documents without review of Designer.

D. Supervise all work with a competent mechanic specifically qualified in mechanical discipline.

1.4 PERMITS

A. Secure and pay for permits, licenses, and inspections for work under this division.

1.5 CODES

A. Comply with all pertinent local, state, and national codes. Refer to Division 01.

1.6 STANDARDS

A. Comply with all pertinent standards. This list is provided as a convenience to Contractor and is not to be considered all inclusive.

1. Sheet Metal and Air-Conditioning Contractors National Association (SMACNA).
2. American Gas Association (AGA).
3. Air Moving and Conditioning Association (AMCA).
4. Air-Conditioning, Heating and Refrigeration Institute (AHRI).
5. American Society of Mechanical Engineers (ASME).

1.7 SUBMITTALS

A. Submit for review complete brochures and shop drawings for materials and equipment proposed in accordance with Division 01.

1. Brochures: Submit complete descriptions, illustrations and specification data for materials and equipment proposed. Clearly indicate proposed items when other items are shown on same sheet. Submit samples on request and/or set up for inspection. Samples will be returned to Contractor.
2. Submittals shall be submitted in line-by-line format. Each submittal shall be provided with a cover letter and supporting documentation indicating how the submittal meets each line of the referenced specification section. All discrepancies between the construction documents and the submitted product shall be clearly identified for engineer evaluation.
3. If a product other than the basis of design is rejected by the engineer for any reason, the Contractor shall provide the basis of design product at no additional cost to the Owner.
4. Shop Drawings:

    a. Control systems.
    b. Complete equipment and piping systems in entire building.

1.8 PROJECT MAINTENANCE MANUALS

A. Prior to final acceptance of project, provide Owner with bound maintenance manuals in accordance with Division 01.

1.9 PROJECT TECHNICAL INSTRUCTION

A. Prior to final inspection of project, provide technical instruction to Owner as follows:

1. Field Instruction: Provide explanation of how systems and equipment are to operate during each season and during emergencies.
2. Field Demonstration: Demonstrate operation and routine maintenance for systems and equipment.

3. Video: Provide digital video of all field instruction and demonstration to Owner at completion.

1.10 PROTECTION

A. Protect all materials and equipment in accordance with Division 01.

B. The contractor must take appropriate precautions, during construction, to prevent unnecessary dust and debris from getting into air and water handling systems by covering equipment, controls and open-ended ducts and pipes as the installation progresses.

1.11 CONSTRUCTION RECORD DOCUMENT

A. Provide construction record documents in accordance with Division 01. Keep at the project one set of drawings and daily record changes at the time they are made. Give drawings to Owner at project completion.

1.12 EXISTING SERVICES

A. Maintain existing services in operation during construction. Coordinate and schedule all service interruptions with Owner.

1.13 OWNER NOTIFICATION

A. Notify Owner two weeks prior to activation of central chilled water and steam service to project.

PART 2 - PRODUCTS

2.1 MATERIALS AND EQUIPMENT

A. Provide materials and equipment of domestic manufacture bearing the U.L. label when such label is available.

PART 3 - EXECUTION

3.1 COORDINATION

A. Coordinate work in accordance with Division 01. Coordinate locations of equipment, ductwork, and piping to eliminate conflict with other divisions.

B. Carefully examine contract documents to be thoroughly familiar with items which require plumbing or mechanical connections and coordination.

C. Provide proper chases and openings. Place sleeves and supports prior to pouring concrete or installation of masonry.

3.2 CUTTING AND PATCHING

A. Repair or replace routine damage caused by cutting in performance of contract.

B. Correct unnecessary damage caused due to installation of mechanical work.

C. Perform repairs with materials that match existing in accordance with the appropriate section of these specifications.

3.3 FLASHING, COUNTERFLASHING, AND SEALING

A. Flash, counterflash, and seal ductwork and piping penetrations of roofs and outside walls.

3.4 TRENCHING, EXCAVATION AND BACKFILLING

A. Provide trenching, excavation, and backfilling necessary for performance of mechanical work accordance with Division 31.

B. Trenching and excavation of rock to be as described in Division 31.

C. Excavate to a depth at least 6" below bottom of pipe and a minimum of 36" above top of pipe. Fill below pipe, around pipe, and minimum of 12" above pipe with sand or Class "B" crushed stone tamped firm and even. Provide topsoil for final layer of dirt (12" minimum). Provide 6" spacing between pipes and between pipe and trench sides. Hand-grade with batterboards placed every 25'. Backfill by hand. Do not use rock or stone above sand or Class "B" crushed stone.

3.5 CONNECTION TO EQUIPMENT

A. Rough-in and connect to sterilizers, lab equipment, kitchen equipment, and Owner furnished equipment and provide a shutoff valve and union at each connection. Provide steam strainer and steam trap for steam equipment. Operating valves and/or controls for this equipment will be provided as an integral part of the equipment. Do not rough-in until shop drawings showing rough-in locations have been reviewed by Designer.

3.6 FOUNDATIONS AND PADS

A. Provide foundations, pads, and bases required for equipment. Concrete to be in accordance with concrete division of specifications.

B. Coordinate proper sizes and locations of foundations, pads, bases, anchors, supports, and other items to be built into structure.

3.7 IDENTIFICATION

A. Identify exposed or accessible piping with stenciling contents indicating pipe contents and direction of flow on piping not more than 20 feet apart, at valves, at access panels, and at least once above each space.

B. Contractors option to identify exposed or accessible piping with snap-on or strap-on type markers. Color code markers in accordance with ANSI. Indicate pipe contents and direction of flow on marker. Install markers on piping not more than 20 feet apart, at valves, at access panels, and at least once above each space.

C. Identify all mechanical equipment with engraved brass, aluminum, or stainless-steel nameplates or tags. Use equipment names and numbers appearing in schedules on drawings. Fasten nameplates to equipment using screws. Glue or adhesive is not acceptable. Fasten tags to equipment using brass, aluminum or stainless-steel chains.

D. Identify each valve with engraved brass, aluminum, or stainless-steel identification tag indicating valve service and sequential identification number. Attach tag to valve handle with brass, aluminum or stainless-steel chain. Provide two bound manuals to Owner listing each valve sequentially and indicating valve manufacturer, style, size, service, normal position, and specific location for each valve.

E. Frame and mount control diagrams and sequences in each equipment room. Use non-fading black and white prints encased in aluminum frame with plexiglass cover.

3.8 CLEANING

A. Repair damaged factory finishes covering all bare places and scratches.

B. Cleaning HVAC Systems Water Piping:

1. Clean all equipment and piping of iron cuttings and other foreign matter as they are installed.
2. Thoroughly flush HVAC water systems with precleaning chemicals designed to remove depositions such as pipe dope, oils, rust, mill scale, and other extraneous materials. Provide dosages of precleaner chemicals recommended by water treatment supplier and add and circulate throughout the water systems. Drain, refill, and flush water systems thoroughly until no foreign matter is observed and total alkalinity of the drain water is equal to that of the make-up water.

3. Do not install devices in which foreign matter could become lodged, such as control valves, until cleaning and flushing are completed. Position valves to bypass chiller, boiler and heat exchanger. Connect supply and return runouts together at each coil location. Make connection of supply and return runouts with short lengths of high-pressure rubber hose and brass fittings. One fitting shall be swivel type to eliminate turning fitting in hose.
4. Fill system at city water make-up connection with all air vents open. After filling, close vents.
5. Start main pump with pressure reducing valve makeup open. Check vents in sequence to bleed off any trapped air in order to assure circulation through all components of system. Verify pumps are properly aligned and bolted down before start-up to prevent damage to seals or couplings. Circulate water for at least two hours and then drain completely to flush out foreign matter.
6. Remove, clean, and replace all strainer baskets. Clean all dirt legs. If indications are found of excessive dirt, repeat the above flushing.
7. Fill the system with fresh water, adding precleaning chemicals designed to remove depositions such as pipe dope, oils, rust, mill scale, and other extraneous materials. Provide dosages of precleaner chemicals recommended by water treatment supplier. Alternate operation of primary and standby pumps and circulate the cleaning solution for 24 hours. Then turn off the pump and completely drain the system.
8. Remove, clean, and replace all strainer baskets. Clean all dirt legs. Replace suction diffuser start-up strainer with conventional strainer. Refill the system with clean water, venting all high points and equipment of air and gases. Bring water systems to operating temperature. Recheck all vent points during this process and remove all air.
9. After the system has been completely cleaned, test the system by litmus paper or other dependable method and leave system on slightly alkaline side (ph 7.5 to 8.5). If the system is still on acid side (ph 7.0 or lower), add water conditioner.

C. Vibration Tests:

1. Test vibration isolation system in accordance with methods and procedures described in the Testing, Adjusting, and Balancing Chapter in the latest edition of ASHRAE Applications Handbook.
2. Verify all vibration isolation systems are free floating and not short circuited by any connection between equipment and building structure.
3. Operate mechanical systems and verify visually and audibly that there is no excessive vibration or noise generated by the system.

END OF SECTION 23 01 00

SECTION 23 05 13 - ELECTRIC MOTORS

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Provide and install electric motors for mechanical and plumbing equipment.

1.2 SUBMITTALS

A. Submittal data is NOT required for products under this section as separate items. It is assumed they will be reviewed with appropriate equipment submittal.

PART 2 - PRODUCTS

2.1 MOTORS

A. Electric motors shall be new NEMA Standard, sized and designed to operate at full load and full speed continuously without causing noise, vibration, and temperature rise in excess of their rating.

B. Motors on belt driven equipment shall have slide rails with adjusting screws for belt tension adjustment. Motors exposed to the weather shall be weather protected.

C. High efficiency electric motors shall be provided for all motors 3 horsepower and greater. Any motor used with a variable speed motor controller shall be high efficiency type and VFD compatible.

D. High efficiency motors shall have efficiency and losses determined in accordance with the latest revisions of IEEE Standard 112. Polyphase squirrel-cage motors rated 1 through 125 horsepower shall be tested by dynamometer method B. The efficiency shall be determined using segregated losses in which stray load loss is obtained from a linear regression analysis to reduce the effect of random errors in the test measurements. Guaranteed minimum full load efficiency shall be as follows:

MINIMUM NOMINAL FULL-LOAD EFFICIENCY (%)		
	Open Motors	Enclosed Motors
Number of Poles	4	4
Synchronous Speed (RPM)	1750	1750
Motor Horsepower		
3	86.5	87.5
5	87.5	87.5
7.5	88.5	89.5
10	89.5	89.5
15	91.0	91.0
20	91.0	91.0
25	91.7	92.4
30	92.4	92.4
40 – 75	93.0	93.0
100 above	94.1	94.5
Refer to Latest Edition of ASHRAE 90.1 for other motor rpm and efficiencies.		

E. Motor sound power levels shall not be greater than recommended in NEMA M61-12.49.

F. Motors shall be provided with drive shafts long enough to extend completely through belt sheaves.

G. Motor characteristics shall be as follows:

1. 120V/1/60 Hz: Capacitor start, open drip-proof type, ball bearing, rated 40 degrees C. continuous rise.
2. 208V and 460V/3/60 Hz: NEMA Design B, normal starting torque, single speed, squirrel cage type, open drip-proof, rated 40 degrees C. continuous rise, with ball bearings rated for B-10 life of 100,000 hours and fitted with grease fittings and relief ports. Provide motors with aluminum end brackets with steel inserts in bearing cavities. Motors located on outdoor equipment to be totally enclosed, fan-cooled housing.

H. Motor horsepower 50 and greater to have part-winding start capabilities.

PART 3 - PRODUCTS

3.1 INSTALLATION

A. Arrange and set motors.

B. Line up motors on direct drive equipment using dial type gauges.

C. Electrical Contractor to make connections and test motor for proper rotation/phasing.

3.2 ADJUSTMENTS

A. All motors together with driven equipment shall be statically and dynamically balanced by equipment supplier, start-up representative, or this contractor using approved balancing equipment. Fan vibration should be limited to manufacturers' recommendations, but should not exceed 2 mils in any case.

END OF SECTION 23 05 13

SECTION 23 05 33 - ELECTRIC HEAT TRACING

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Furnish and install a complete U.L. listed system of heaters, components, and controls to prevent pipelines indicated on drawings from freezing.

PART 2 - PRODUCTS

2.1 EQUIPMENT REQUIREMENTS

A. Provide self-regulating type heat tracing consisting of two (2) 16 AWG nickel coated-copper bus wires embedded in parallel in a radiation-crosslinked polymer core that varies its power output to respond to temperature all along its length, allowing the heater to be crossed over itself without overheating, to be used directly on plastic pipe, and to be cut to length in the field. The heater shall be covered by a radiation cross-linked modified polyolefin dielectric jacket. The heater shall be equivalent to Raychem XL-Trace, Chromalox CPR, or approved equal.

B. To prevent overheating, the heater shall have a self-regulating index of at least 90 percent. The self-regulation factor is defined as the percentage reduction, without thermostatic control, of the heater output going from 50 degree F. pipe temperature operation to 140 degree F. pipe temperature operation.

C. The heater shall operate on a line voltage of **277** volts without the use of transformers.

D. The heater shall be sized according to the following table. The required heater output rating is in watts per foot of pipe length at 40 degrees F.

Pipe Size	**Heater Minimum Watts Per Foot**
3 inch and less	5
4 to 6	8
8	10
10 to 16	16
18 and larger	20

E. Power connection, end seal, splice, and tee kit components shall be provided for installation in the field.

F. The system shall be controlled by a ambient sensing thermostat set at 40 degrees F. either directly or through an appropriate contactor.

G. Ground fault circuit breaker shall be provided as required by Section 427-22 of the National Electric Code.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install heater in strict accordance with manufacturers' published installation instructions and Article 427 of the National Electric Code.

B. Apply the heater spirally on the pipe after piping has been successfully pressure tested. Secure the heater to piping with cable ties or fiberglass tape. Heat tracing shall be applied to pipe before applying insulation. See Section 23 07 10 for insulation requirements.

C. Apply "electric traced" signs to the outside of the thermal insulation at least once every 50 feet.

3.2 TESTS

A. After installation and before and after installing the thermal insulation, subject heater to testing using a 5000 VDC megger. Minimum insulation resistance should be 20 megohms regardless of length.

B. The installer shall test both heating cable bus wires to verify the connection of any splices or tees.

END OF SECTION 23 05 33

SECTION 23 05 48 - VIBRATION ISOLATION

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Isolate equipment as shown on drawings and specified herein with factory-fabricated vibration isolators in accordance with recommendations in the latest edition of ASHRAE Applications Handbook. Provide isolators of proper sizes and weight loading to meet the requirements.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Kinetics Noise Control, Vibro-acoustics or approved equal. Provide isolators by a single manufacturer.

2.2 FIBERGLASS OR NEOPRENE PADS

A. Provide Kinetics Model KIP for:

1. Chilled water pumps.

2.3 SPRING AND RUBBER ISOLATION HANGERS

A. Provide Kinetics Model SFH or SRH for:

1. Suspended air handling units (minimum 2" deflection).
2. Suspended centrifugal fans (minimum 2" deflection).
3. Horizontal fan coil units (minimum 1.0" deflection).
4. First three (3) piping hangers on each side of air handling units, pumps, and chillers (minimum 1.5" deflection).

2.4 CONCRETE INERTIA BASES

A. Provide Kinetics Model CIB inertia bases with Kinetics Model FDS spring isolators for:

1. Chilled water pumps. Base to be installed on slab-on-grade according to manufacturers recommendations.

2.5 FLEXIBLE PIPE CONNECTORS

A. Provide Metraflex or approved substitute twin-sphere flexible rubber pipe connectors with female unions or floating flanges on piping connections to equipment subject to vibration.

B. Provide connectors rated for 150 PSI working pressure.

C. Provide flexible pipe connectors for the following:

1. Water connections to chillers.
2. Water connections to pumps.

2.6 OUTDOOR APPLICATIONS:

A. All isolators located outside exposed to weather shall be corrosion resistant construction with hot dip galvanizing or PVC coating.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install vibration isolation in accordance with the isolator and equipment manufacturer's published installation instructions.

B. Size vibration isolation in accordance with weight distribution, pull or the imposed torque of actual equipment provided.

END OF SECTION 23 05 48

SECTION 23 05 49 - BASIC MATERIALS AND METHODS FOR HVAC

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Work required under this section of specifications consists of basic materials and methods applicable to work under Division 23.

PART 2 - PRODUCTS

2.1 FOUNDATIONS AND PADS

A. Provide foundations, pads, and bases required for equipment. Concrete to be in accordance with concrete division of specifications.

B. Coordinate proper sizes and locations of foundations, pads, bases, louvers, anchors, supports, and other items to be built into structure.

2.2 FASTENINGS TO STRUCTURES

A. Provide structural fastening devices for equipment, materials, piping and ductwork. Devices to be concrete inserts, expansion shields and lag bolts, and through bolts-washers-nuts. All bolted devices to use jamb nuts. Inserts to be continuous type as manufactured by Unistrut or approved substitute. Install per manufacturer's published installation instructions in lengths to suit specific application, complete with spring nuts, end caps, and plastic-coated filler to prevent concrete seepage.

B. Use of power drive "shot-pins" is permitted only for ducts 20" in width and smaller and single pipes 1" and smaller.

2.3 ACCESS PANELS

A. Provide ceiling and wall access panels for installation by other Divisions. Coordinate locations so panels will provide proper access to equipment served. Notify Designer of proposed wall or ceiling access panel locations prior to installation of such panels. Minimum size: 30" x 20".

B. Panels shall be manufactured by Bilco or approved substitute. Provide panels with minimum 16-gauge steel construction with screwdriver operated locks and primer finish.

C. Provide fire-rated panels for installation in fire-rated partitions.

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION 23 05 49

SECTION 23 05 93 - TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Perform test and balance work by a Test and Balance Agency which is engaged solely in full time test and balance work, is a member of the Associated Air Balance Council (AABC) or National Environmental Balancing Bureau (NEBB).

B. Perform test and balance in accordance with AABC or NEBB Standards.

C. Contract to the Test and Balance Agency shall be issued by the contractor. Coordination with the agency at the job site shall be the responsibility of the contractor in order to ensure proper scheduling and operation of the systems. All correspondence (reports, letters and communications) between any parties shall have copies sent directly to the designer and contractor.

D. The TAB agency shall review construction plans and specifications. If any discrepancies are noted which would hinder balancing, notify the designer with copy to the contractor. Make inspections of the job during construction for proper installation of the system(s) and of balancing aids in the system(s). Any discrepancies noted shall be brought to the attention of the contractor and designer. The number of inspections vary with the size and complexity of the job and shall be adequate for the purpose intended. Report ALL job visits in writing - MANDATORY.

E. The TAB agency shall work in close coordination with the contractor in calibrating all water flow stations and pipe mounted differential pressure sensor / transmitters. The tests shall be documented and included in the final TAB report.

1.2 RESPONSIBILITIES OF PROJECT CONTRACTOR

A. The contractor shall:

1. Provide approved Test and Balance Agency with copy of plans and specifications upon issue of construction documents.
2. Have the building and HVAC systems in operational readiness for TAB work to begin.
3. Correct prompt deficiencies of materials and workmanship identified as delaying completion of TAB work.
4. Be responsible for any added costs to the owner resulting from his failure to have the building and HVAC systems ready or from his failure to correct deficiencies promptly.

B. Complete operational readiness of the building requires that construction status of the building shall permit closing of doors, windows, ceilings installed, etc., to obtain projected operating conditions.

C. Complete operational readiness of the air conditioning systems requires that the following be accomplished:

1. Air Distribution Systems:

   a. Verify installation conforms to design. All supply, return and exhaust ducts terminated and pressure tested for leakage as required by specifications.
   b. All volume, control, fire and smoke dampers properly located and functional. All dampers shall be fully open. MVD gradients and spin damper handles should be exposed through insulation. Dampers serving requirements of minimum and maximum outside, return and relief air shall provide tight closure and full opening, smooth and free operation.
   c. All supply, return, exhaust and transfer grilles, registers, diffusers, and filters installed.
   d. Air handling systems, units and associated apparatus, such as heating and cooling coils, filter sections, access doors, etc., shall be sealed to eliminate bypass or leakage of air.
   e. All fans operating at full load and verified for freedom from vibration, proper fan rotation and belt tension; heater elements in motor starters to be of proper size and rating. Check motor amperage and verify that it is under nameplate rating.

2. Water Circulating Systems:

   a. Check and verify pump alignment and rotation. Verify location of thermometers, gages, and PT test plugs.
   b. Open all valves to full open position. Close bypass stop valves. Set mixing valves to full flow through system components. Remove and clean all strainers. Verify specified pipe cleaning has taken place. Repeat operation until circulating water is clean.
   c. Record pump motor amperage on each phase and voltage after reaching rated speed. Readings shall not exceed nameplate rating. Verify heater elements in motor starters to be of proper size and rating.
   d. All water circulating systems shall be full and free of air; expansion tanks set for proper water level; all air vents installed at high points of systems and operating freely. System static pressure to be set minimum 5 psig above highest system elevation.
   e. Check and set operating temperatures of heat exchangers to design requirements.
   f. Verify that piping to coils is complete and set for counter flow. Verify location of thermometers, gauges, PT test plugs, and flow balancing/measuring valves.

3. Automatic Controls:

   a. Verify that all control components are installed and functional in accordance with project requirements, including all electrical interlocks, damper sequences, temperature resets, and safeties.

b. Verify that pressure controllers are calibrated and control variable speed motor controllers as required to maintain a stable pressure.
c. All controlling instruments calibrated and set for designed operating conditions.

4. Notification of System Readiness: After completion of the work above, the contractor shall notify the TAB firm and designer certifying that the work has been accomplished and that the building and piping systems are in readiness for testing, adjusting, and balancing.

D. The contractor shall provide and coordinate services of qualified, responsible contractors, suppliers and personnel as required to correct, repair, or replace any and all deficient items or conditions found during the testing, adjusting and balancing period.

E. In order that all systems may be properly tested, balanced, and adjusted, the contractor shall operate systems at his expense for the length of time necessary to properly verify their completion and readiness for TAB.

F. Project schedules shall provide sufficient time to permit the completion of TAB services prior to owner occupancy.

G. The plans and specifications have indicated valves and miscellaneous adjustment devices for the purpose of adjustment to obtain optimum operating conditions, and it will be the responsibility of the contractor to install these devices in a manner that will leave them accessible and readily adjustable. Should any such device not be readily accessible, the contractor shall provide access as requested by the TAB firm. Also, any malfunction encountered by TAB personnel shall be reported to the contractor and designer and corrected by the contractor immediately so the balancing work can proceed.

H. The TAB agency shall be provided with either appropriate control system software or the contractor's handheld device for setting the terminal boxes and entering / updating terminal box flow coefficients, and for placing equipment in the correct mode for testing. This software and / or equipment shall be provided to the TAB agency free of charge for the duration of the project, and shall be returnable to the contractor upon completion of the project. Providing the TAB agency laptop software for placing equipment in the proper operating mode for testing, and for entering terminal box flow coefficients, allows the TAB agency to program the boxes as it completes them, and is the most effective use of both the contractor's and TAB agency's time.

1.3 QUALIFICATIONS OF THE TAB CONTRACTOR

A. The firm shall submit six (6) completed projects of like size and scope. Provide references for each project.

B. The test and balance firm shall submit a resume for the individual proposed to directly supervise the project. The supervisory personnel for the test and balance firm shall be certified test and balance engineers. All project managers and technicians shall be permanent, full-time employees of the agency.

C. The test and balance firm shall submit a list of its calibrated instrumentation to perform the work.

1.4 DOCUMENTS

A. The contractor shall furnish to the TAB firm the following:

1. One set of mechanical specifications.
2. Three sets of mechanical drawings.
3. All pertinent addenda and change orders.
4. One set of control submittal drawings.
5. Approved submittal data on equipment installed, and related changes as required to accomplish the TAB test procedures outlined below.

PART 2 - PRODUCTS – NOT APPLICABLE

PART 3 - EXECUTION

3.1 RESPONSIBILITIES OF THE TAB FIRM

A. The TAB personnel shall check, adjust, and balance the components of the HVAC system which will result in minimum noise, specified temperature, and air flow conditions in the conditioned spaces of the building while the equipment of the system is operating economically. This is intended to be accomplished after the system components are installed and operating as provided for in the contract documents.

3.2 LIAISON AND EARLY INSPECTION

A. The personnel on the job shall act as liaison between the owner, designer and contractor. They shall inspect the installation of piping systems, ductwork systems, control systems, and other component parts of the HVAC systems during the construction stage to verify proper arrangement and adequate provisions for the testing and balancing.

B. During the balancing process, as abnormalities and malfunctions of equipment or components are discovered by the TAB personnel, the contractor shall be advised in writing so that the condition can be corrected by the contractor. The TAB firm shall suggest solutions to noted problems. Data from malfunctioning equipment shall not be recorded in the final TAB report.

3.3 THE TAB REPORT

A. TAB activities shall culminate in a report to be provided in triplicate to the designer. The intent of the final report is to provide a reference of actual operating conditions for the owner's operating personnel.

B. All measurements and recorded readings (of air, water, electricity, etc.) that appear in the reports must be done on-site by permanently employed technicians or engineers of the firm.

C. All comment sheets (punch lists) shall be signed by the contractor to acknowledge receipt. Any outstanding items at the time of completion shall be included in the report.

D. The report shall be certified and approved by the firm's test and balance engineer. The report shall be recorded on standard forms.

3.4 ACTUAL TESTING AND BALANCING PROCEDURES

A. Airside:

1. Supply Air:

a. Fans checked for rotation, amperage, static pressure, etc.
b. Main supply duct pitot tube traverse and adjustment of fan speed to produce within 5% design cfm while maintaining minimum system static pressure for proper terminal box operation.

2. Return Air:

a. Fans checked for rotation, amperage, static pressure, etc.
b. With supply system in the maximum mode, traverse and adjust return fan to design cfm.
c. With supply system in the maximum mode, proportion return inlets to within 5% of design cfm.

3. Outside Air:

a. Fans checked for rotation, amperage, static pressure, etc.
b. With supply system in the maximum mode, traverse and adjust minimum outside air damper and/or fan to within +5% design cfm.

4. Exhaust Air:

a. Fans checked for rotation, amperage, static pressure, etc.
b. With supply system in the maximum mode, traverse and adjust exhaust fan to design cfm.
c. Proportion exhaust inlets to within 5% of design cfm.

5. Diffusers, Registers, and Grilles:

a. Balance each supply, return and exhaust air outlet within 5% of design cfm.
b. Check and/or adjust pressure relationships so that each positive pressure and each negative pressure area is at least 10% positive or negative as appropriate.

6. After completion, take total air-handling system static profile and record all final statics, amperages, rpm, cfm, etc.

B. Waterside:

1. Chilled Water:

a. Check system for cleanliness.
b. With all chilled water valves calling for full cooling, test, set and record each pump head and flow.
c. Test, set, and record pressure drop and flow through each chiller.
d. Test, set and record pressure drop and flow through each flow balancing station.
e. Test, set and record pressure drop and flow through each cooling coil.
f. Verify that piping system is vented.
g. Verify removal of pump start up strainer and replacement with operating strainer.

C. Controls:

1. AHU Controls:

a. Check temperature controls for proper calibration and setpoint.
b. Check economizer controls for proper damper operation and control calibration.
c. Check supply/return volumetric synchronization system under maximum and minimum conditions for proper operation.
d. Check static pressure control under maximum and minimum conditions for proper operation.

2. Chiller Controls:

a. Verify chiller controller is set at design chilled water temperature.
b. Verify central chiller control panel properly stages chillers.

3. Thermostats and Controllers:

a. Check for proper control of valves, dampers, terminal boxes, exhaust fans, etc.
b. Set at design set point.

D. Capacity and Performance Test:

1. Cooling Coils:

a. Test, set and record pressure drop and flow through each coil.
b. Measure entering and leaving dry and wet bulb air temperatures with glass stem, mercury thermometers accurate to 1/2 degrees F.

c. Measure entering and leaving water temperature with glass stem, mercury thermometer if thermometer wells are provided. If P.T. plugs are provided, use a bi-metal thermometer which reads in 1 degree F. increments and use the same thermometer for both supply and return water temperature measurements.
d. Record final temperatures, BTU/HR. and GPM.
e. Convert actual test conditions to design conditions to insure design coil capacities at design temperatures.

2. Heating Coils:
a. Test, set and record pressure drop and flow through each coil.
b. Measure entering and leaving dry and wet bulb air temperatures with glass stem, mercury thermometers accurate to 1/2 degrees F.
c. Measure entering and leaving water temperature with glass stem, mercury thermometer if thermometer wells are provided. If P.T. plugs are provided, use a bi-metal thermometer which reads in 1 degree F. increments and use the same thermometer for both supply and return water temperature measurements.
d. Record final temperatures, BTU/HR. and GPM.
e. Convert actual test conditions to design conditions to ensure design coil capacities at design temperatures.

3. Chillers:

a. Record full load entering and leaving chilled water temperatures with glass stem, mercury thermometers accurate to 1/2 degree F.
b. Record GPM at time of test.
c. Record amperage and voltage.
d. Perform log-test for a minimum of one hour taking readings at least every ten minutes.
e. Average all readings and compute test capacity in BTU/HR. and in tons.
f. Average all readings and compute actual kw/ton of chiller.

4. Thermostat Calibration:

a. Measure and record dry and wet bulb temperatures at each thermostat.
b. Report any thermostat which is not controlling with +/-1-1/2 degree F.

5. Control Temperature Readouts:

a. Test actual temperature next to sensor (if possible) and compare to readout.
b. Report any sensor which is not within +/-1/1-2 degrees F.

3.5 REPORTS

A. Problems Encountered: Any items not installed, improperly installed or not functioning properly shall be reported to the contractor.

B. Final Report:

1. Any unresolved problems shall be reported in a general remarks section in front of the test and balance report.
2. Any unusual operations or pertinent remarks which may aid the maintenance personnel or ease the reading of the report shall be made in the general remarks section of the report.
3. All operating data and final tests shall be reported in the final report. This data shall include, but not necessarily be limited to the scope of work outlined above.
4. TAB contractor shall compile an Excel spreadsheet for all terminal boxes, listing each box by its unique identification number, the inlet flow area established by the box manufacturer, the manufacturer's gain factor for the box, final TAB calibrated gain factor for the box if field calibrated, and the ratio of the calibrated gain factor to the manufacturer's gain factor.

3.6 CALLBACK

A. Test and Balance Agency shall retest any unresolved problems noted in the final report. The revised results shall be forwarded after completion of test.

B. At the discretion of the designer before final acceptance of the TAB report, the report data shall be verified one time on the job site by selection of random check points in the presence of the designer. Representatives of the testing firm shall be present and provide the necessary equipment for test data verifications.

C. The firm shall be responsible for testing, adjusting, balancing, and reporting on the performance of all fans, dampers, air distribution devices, pumps and heat exchangers, the flow through all coils, pumps and heat exchangers, and the power consumption of all motors. The contractors and the suppliers of the equipment installed shall cooperate with the balancing agency to provide all necessary data on the design and proper application of the system components and shall furnish all labor and material required to eliminate any deficiency.

D. Make one (1) inspection within ninety (90) days after occupancy of the building to insure that satisfactory conditions are being maintained.

3.7 OPPOSED SEASON TESTING

A. This service allows for testing of equipment that, due to extreme weather conditions, cannot be accurately tested at the time of the initial balance. If a project is balanced during the summer, the opposed season testing is performed during the winter months and vice-versa.

B. During the opposed season testing, any necessary modifications to the initial adjustment required to produce optimum operation of the system components shall be made to produce the proper seasonal conditions in each conditioned space. At the time of opposite season testing, the designer and owner shall be given timely notification before any readings or adjustments are made so that he may participate.

END OF SECTION 23 05 93

SECTION 23 07 10 - INSULATION

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Contractor shall provide all necessary labor, materials, tools, and equipment to perform work required on the drawings and specified herein.

B. Certain equipment and/or systems to be factory insulated by manufacturer. Factory insulation materials to be as specified in applicable sections of the specifications.

C. All pipe fittings, valves, and strainers in insulated pipe systems to be insulated.

D. Thermal resistance "R" values used herein are expressed in units of "Hour, Degrees F., Sq. Ft./BTU per Inch of Thickness" on a flat surface at a mean temperature of 75 degrees F.

E. Note that where electric cable wrap is called for, insulation is to be applied over cable.

F. "Contractor's Option" referred to in Materials below indicates optional materials which may be used as equals.

1.2 DEFINITIONS

A. "Exposed" equipment, ducts, and piping are areas which will be visible without removing ceilings or opening access panels.

B. Outdoors is considered exposed to the weather.

C. Underground is buried, whereas in a trench below grade is considered concealed.

1.3 CERTIFICATION/QUALITY ASSURANCE

A. Products shall meet applicable national, state, and local building codes and be U.L. (or other recognized testing lab) listed for intended service.

B. All insulations, jackets, adhesives, coatings, sealers, and tapes shall have a flame spread rating of 25 or less and smoke development rating of 50 or less when tested in accordance with ASTM E-84, NFPA 225, U.L. 723, and further must meet the requirements of NFPA 90-A and applicable building, plumbing, and mechanical codes.

C. All insulation materials shall be delivered and stored in manufacturers' containers and kept free from dirt, water, chemical, and mechanical damage. Under no circumstances shall insulation applied to exterior ductwork be allowed to get wet prior to final material covering.

D. Insulation shall be applied in a workmanlike manner by experienced, qualified tradesmen.

E. Insulation shall not be applied until all pressure testing has been completed, inspected, and released for insulation application.

F. Surfaces shall be clean and dry.

G. Insulation joints shall be butted firmly together and all jackets and tapes shall be smoothly and securely installed.

H. Insulation for duct, pipe, and equipment for above grade exposed to weather outside building shall be certified as being self-extinguishing for 1" thickness in less than 53 seconds when tested in accordance with ASTM D-1692.

1.4 APPLICABLE CODES AND STANDARDS

A. ASTM E-84.

B. U.L. 723.

C. NFPA 90-A.

D. State of Florida Energy Code.

PART 2 - PRODUCTS

2.1 MATERIALS FOR PIPE AND EQUIPMENT

A. Materials for Pipe and Equipment: Provide factory pre-molded or shop or site mitered segment type insulation for pipe, pipe fittings, and valves. Fitting insulation to be of same thickness and material as adjoining pipe insulation. All insulation and related materials such as tape and mastic to meet applicable building code requirements for fire and smoke development.

1. Cellular Glass (Foamglass): Pittsburgh Corning "Foamglass." Product must be guaranteed by manufacturer to have a continuous operational temperature limit of 250 degrees F. and a minimum "R" value of 3.7 per inch (K=0.27) at 75 degrees F mean temperature. Vapor-barrier mastic for application to below ambient pipe insulation shall be fungus resistant per ASTM D 5590 with 0 growth rating; Water based; Permeance per ASTM E 96, Procedure B, 0.013 perm or less at 43-mil dry film thickness suitable for indoor and jacketed outdoor use. Products: Foster 30-80 AF. Color: White. For all butt joints, a pliable insulation joint sealant shall be used. Products: Foster 95-50 or Childers CP-76. Use foamglass for the following services:

    a. Make-up water piping: 1" thick.
    b. With saddles instead of other piping insulation (fiberglass, flexible tubular) to prevent crushing of insulation at hangers.

2. Flexible Tubular: Provide 25/50 rated, closed-cell, flexible tubular rubber type pipe insulation. Product to have continuous operational temperature limit of 200 degrees F. and a minimum "R" value of 3.7 per inch (K=0.27) at 75 degrees F mean temperature. Product to be Armstrong AP Armaflex or approved equal pipe insulation. Use flexible tubular for the following services:

    a. Moisture condensate drains: 1" thick.
    b. Runs of waste lines carrying cold condensate from air conditioning equipment: 1" thick.
    c. Refrigerant suction lines for split systems: 1" thick.
    d. Make up water piping 2" and under (contractor option): 1" thick.
    e. All refrigerant lines for Variable Refrigerant Flow (VRF) systems: 1” thick.

3. Flexible Sheet: Provide 25/50 rated, closed-cell, flexible sheet rubber type insulation, having a minimum "R" value of 3.7 per inch (K=0.27) at 75 degrees F mean temperature and continuous operational temperature limit of 200 degrees F. Product to be Armstrong "Armaflex II" or approved equal. Use flexible sheet insulation for the following services:

    a. Chiller cooler, suction piping, and any chilled water pipe connections, housings, and other portions of the chiller which might sweat: 1" thick.
    b. Chilled water pump casings and flanges: 1" thick.

2.2 MATERIALS FOR DUCTS

A. Blanket Type Duct Insulation: Provide minimum 3/4 pound per cubic foot density, flexible blanket fiberglass duct insulation with FSKL aluminum foil vapor barrier facing and 2" tab. Insulation shall have minimum 'R' value of 3.4 per inch (K=0.29) at 75 degrees F mean temperature. Product to be Manville "Microlite" or equivalent standard duct wrap by CertainTeed, Knauf, or Owens-Corning. Use blanket type duct insulation for the following:

1. Indoor Ductwork: 2.2" thick.

B. Board Type Duct Insulation: Provide minimum 3 pound per cubic foot density, semi-rigid fiberglass duct insulation with FSKL aluminum foil vapor barrier facing. Insulation shall have a minimum 'R' value of 3.8 per inch (K=0.26) at 75 degrees F mean temperature. Product to be Manville "800 series Spin-Glas" or equivalent by CertainTeed, Knauf, or Owens-Corning. Use board type duct insulation for the following services:

1. Exposed supply, return and outside air ducts within equipment rooms subject to damage: 1-1/2" thick.

2. Outdoor Ductwork: 2.2" thick.

2.3 MATERIALS FOR FITTINGS, VALVES, AND SPECIAL COVERINGS

A. Provide coverings and finishes for specific items hereinafter specified.

1. Use pre-molded insulation fabricated by the manufacturer of insulation material or shop or site mitered segment type insulation for: All pipe fittings, elbows, tees, valves, and couplings.
2. Contractor's option to provide factory pre-molded one-piece PVC insulated fitting covers, precut fiberglass insulation inserts, and necessary installation materials for all pipe fittings. Materials to be equal to Manville Zeston white, U.V. resistant, 25/50 rated, 20 mil thickness insulated PVC fitting covers and insulation inserts.

B. For heat exchangers, air separators, large pipes, etc., in systems operating over 60 degrees F., when exposed-to-view inside building or in equipment rooms, cover insulation with a smoothing coat of Keane Powerhouse cement, one layer of white colored glass mesh embedded and finished with Foster 46-50 mastic or Childers CP-10 / CP-11 mastic.

C. For pipe fittings, valves, strainers, air separators, and other irregular surfaces, in systems operating below 60 degrees F., when exposed to view inside building or in equipment rooms, cover insulation with white colored glass mesh embedded in white, fungus resistant vapor barrier coating Foster 30-80 AF. Coating shall meet ASTM D 5590 with 0 growth rating.

D. Fabricate and install readily removable insulation caps to facilitate service and maintenance accessibility to all strainers including suction diffusers in systems operating below 60 degrees F.

E. For any service operating below 70 degrees F, when above grade exposed-to-the-weather outside building and exposed in equipment rooms, cover straight pipe insulation with 0.016" thick aluminum jacket equivalent to ITW or RPR and cover valves and fittings with .024" thick aluminum factory formed covers equivalent to Childers Ell-Jacs.

F. For flexible tubular pipe and fitting insulation when exposed-to-view inside building or exposed to the weather, finish with two coats of paint, custom color blended to match surrounding surfaces.

G. For externally insulated sheet metal ducts when above grade exposed-to-the-weather outside building, cover duct insulation with FlexClad 400 self-adhering weather and vapor barrier membrane by FlexClad or equal by Polyguard having proven ability to withstand a wide range of temperatures without cracking or crazing and that is highly resistant to damage by bumping and abrasion. Product color to be white unless otherwise noted. Apply in accordance with manufacturers' published instructions.

H. When specifically approved by designer, when it is impossible to completely insulate pipe, fittings, or valves with specified insulation, Armstrong Armaflex insulation tape may be used to prevent condensate drip on small piping. Use of cork insulation tape is prohibited.

PART 3 - EXECUTION

3.1 GENERAL

A. No insulation shall be cut where a hanger is located. If hangers have been installed by pipefitter tradesmen which violates this strict requirement, notify Designer immediately.

B. Piping and ductwork systems shall be tested and found free of all leaks prior to installation of insulation covering.

C. All surfaces shall be clean and dry when covering is applied. Covering to be dry when installed and during application of any finish, unless such finish specifically requires a wetted surface for application.

D. All adhesives, cements, and mastics shall be compatible with materials applied and shall not attack materials in either wet or dry state.

E. Install insulation using professional insulators who have adequate experience and ability.

F. Exposed-to-view insulation shall have a well tailored appearance.

G. See Section 23 22 01 for sleeves and insulation requirements.

H. Stop all duct coverings, including jacket and insulation, at fire and smoke dampered penetrations of partitions. "Fan-Out" or extend jacketed insulation at least 2" beyond angle frames of dampers and secure insulation to partition. Maintain vapor barrier. Where insulated duct access door is not used, install covering over damper access panel so as to be readily removable and identifiable.

I. Treat insulated pipe and duct surfaces in equipment rooms and where exposed to normal view, so surfaces may be painted with water base latex paint. Use of mastics, adhesives, or jacketing which cause "bleeding" is prohibited.

J. Pipe hanger insulation shields and/or saddles shall be properly centered inside the pipe hanger to ensure that the piping insulation is not damaged.

K. Pipe hanger insulation shields shall be fabricated with a minimum metal gauge thickness in compliance with MSS SP-69.

3.2 INSTALLATION OF DUCT COVERING

A. Apply jacketed blanket type fiberglass covering to ducts pulled snug but not so tight as to compress corners more than 1/4". Use insulation having 2" tab, or cut insulation long enough to allow for "peel off" of insulation from jacket to effect a minimum overlap of 2". Secure 2" jacket laps using equivalent of Foster 85-75 or CP-82 adhesive and staple lap with flare type staples on 2" centers. Cover standing seams, stiffeners, and braces with same insulation blanket, using 2" jacket lap and staple lap as hereinbefore outlined. Cover and seal all staples with Foster 30/80 AF, fire resistant vapor barrier coating reinforced with glass cloth.

B. For duct 24" or wider, mechanically fasten insulation to duct bottom, using weld pins or nylon "stick-clip" base plates having self-locking coated metal or nylon discs. Locate fasteners on not over 12" centers laterally and longitudinally. Seal pins as above.

C. For ducts more than 20” deep, mechanically fasten insulation to duct sides, using one row of pins, plates, or discs located on not over 12" centers longitudinally and equidistant laterally between duct top and bottom. For ducts over 24" deep, apply fasteners as before only using minimum of two rows.

D. Apply jacketed board type fiberglass covering to ducts using weld pins or nylon "stick-clip" base plates having self-locking coated metal or nylon discs. Locate fasteners on not over 12" centers laterally and longitudinally. If insulation is grooved to fit around corners, in order to eliminate as many joints as possible, pin as required to hold insulation tight to duct, especially on bottom of duct. Seal pins and joints with Foster 30-80 AF reinforced with glass mesh.

E. Cover all joints, rips, tears, punctures, disc heads, staples, or breaks in vapor barrier jacket with 4" wide woven glass fabric tape embedded in Foster 30-80 AF fire resistant vapor barrier coating. PRESSURE SENSITIVE TAPE NOT ALLOWED.

F. Prior to application of flexible sheet insulation, thoroughly clean all metal surfaces, making sure that all dirt, scale, loose paint, plaster, and oil have been removed and that surfaces are dry. If surface has been primed, test a 2 square foot section using adhesive equivalent to Armstrong 520, Foster 85-75 or Childers CP-82 in order to determine whether solvent in adhesive will loosen or lift the primer. If primer is loosened, then remove it. When testing proves acceptable, adhere insulation with smooth side out, using thin but adequate coating of same adhesive. Follow manufacturers' instructions. Coat all butt edges of each sheet. Stagger all joints. Insulate all standing seams or flanges with same thickness of insulating material as that used on main surface. Seal all butt joints, miter joints, and torn or damaged insulation with adhesive.

G. Ductwork manual volume damper (MVD) handles, airflow station pressure ports, access door handles, duct-mounted instrumentation, etc., shall be left exposed and/or accessible above the insulation vapor barrier.

3.3 INSTALLATION OF PIPE AND EQUIPMENT COVERING

A. Where flexible tubular insulation is used on piping sized 2" and larger, insert a section of foamglass insulation at hanger or support points between pipe and metal shield for full length of shield to prevent crushing of insulation. Insulation thickness to be same as adjoining insulation. Where insulation passes through pipe hangers and across trapeze supports, 12" long metal saddles shall be used. On cold pipe, vapor barrier should be carried through the hanger and sealed.

B. Foamglass insulation shall be strictly applied as follows:

1. The inside full surface of the insulation and both the circumferential and longitudinal joints shall be buttered with fire-resistive pliable joint sealant. Voids and cracks shall be filled with sealant. Sealant shall be Foster 95-50, Childers CP-76 or equal. Insulation shall be secured with 1/2" wide aluminum bands on 12" centers.
2. The circumferential joints shall be staggered.
3. Block type insulation shall be adhered by stick-clips or bands, in addition to the sealant, as required to provide support for the insulation.
4. Finish in concealed locations shall be the bare insulation.
5. Finish in equipment rooms and elsewhere where exposed-to-view shall be white 8 oz. canvas and Foster 30-36 or Childers CP-50A MV1 lagging adhesive/coating, paintable jacket.

C. Apply flexible tubular insulation to pipe and fittings using the slip-on method with all joints tightly fitted and sealed with Armstrong 520, Foster 85-75, Childres CP-82 adhesive or approved equal. Seal butt joints, miter joints and torn or damaged insulation with adhesive.

D. Prior to application of flexible sheet insulation, thoroughly clean all metal surfaces, making sure that all dirt, scale, loose paint, plaster, and oil have been removed and that surfaces are dry. If surface has been primed, test a 2 square foot section using adhesive equivalent to Armstrong No. 520, Foster 85-75, Childers CP-82 in order to determine whether solvent in adhesive will loosen or lift the primer. If primer is loosened, then remove it. When testing proves acceptable, adhere insulation with smooth side out, using thin but adequate coating of same adhesive. Follow manufacturers' instructions. Coat all butt edges of each sheet. Stagger all joints. Insulate all standing seams or flanges with same thickness of insulation material as that used on main surface.

E. Apply PVC insulated fitting covers and precut insulation inserts as follows:

1. Installation for cold systems:

a. Position, tuck, and fold the fiberglass insulation insert as described above in steps (a) and (b) for hot systems.
b. Apply a vapor barrier mastic around the edges of the adjoining pipe insulation. Apply the mastic along the inside of the fitting cover throat overlap seam.
c. Place the fitting cover over the insulation, lapping the mastic-covered edge over the other side of the throat seam.
d. Apply color-matched, pressure-sensitive tape over the circumferential joints. The tape should extend over the adjacent pipe insulation and overlap itself by at least 2" on the downward side of the lap.

END OF SECTION 23 07 10

SECTION 23 09 23 - DIRECT DIGITAL CONTROL/BUILDING AUTOMATION SYSTEM (DDC/BAS)

PART 1 - GENERAL

1.1 DESCRIPTION

A. Direct Digital Control/Building Automation Systems (DDC/BAS) shall be Johnson Controls, Siemens, Automated Logic, Honeywell, or approved equal.

B. The work specified under this section of the specifications includes furnishing, installing, programming, and placing into operation the DDC/BAS systems. Systems shall be furnished, installed, and warranted by the manufacturer.

C. The DDC/BAS systems shall be furnished and installed under this section of the specifications and shall consist of microprocessor based digital system controllers. The systems shall have the ability for extension to other buildings by web addressable server. The systems shall be complete in every respect, including all auxiliary and accessory items as required, and shall be thoroughly coordinated so as to provide a compatible and completely workable system.

D. Provide a complete control system including electrical interlocks, wiring, conduit, relays, switches, control transformers, and other devices as required to accomplish automatic control of the mechanical systems. Refer to drawings for details.

E. All systems shall be guaranteed against defects of any nature and to operate properly for a period of not less than 12 months after final acceptance of the job by the Owner. During this period, the BAS manufacturer shall service and adjust the systems as required for proper operation, replacing components as required.

F. The Owner has hired an independent Cx agent to commission the mechanical and controls systems serving this facility and the Cx procedures shall include a final Functional Performance Test. The contractor should refer to Specification 23 0811, MECHANICAL AND ELECTRICAL SYSTEMS COMMISSIONING, in order to be apprised of, and become familiar with his responsibilities and accountabilities throughout the Cx process.

G. The contractor shall work in close cooperation with the TAB agency in calibrating all airflow and water flow stations and all duct and pipe mounted differential pressure sensor/transmitters.

H. Commissioning of the mechanical and control systems is part of this project. The Cx procedures shall include Prefunctional Performance Testing and final Functional Performance Test. The contractor should refer to Cx Specification in order to be apprised of, and become familiar with his responsibilities and accountabilities throughout the Cx process.

I. The controls contractor shall furnish the test and balance contractor with appropriate DDC system software available to assist in the TAB process. The contractor shall work in close cooperation with the TAB agency in calibrating all airflow and water flow stations and all duct and pipe mounted differential pressure sensor/transmitters. The controls contractor shall provide a technician for 8 hours to assist/train the TAB technician in the coordination/interface of the BAS with TAB activities.

J. Submit complete shop drawings, equipment and component brochures, list of control valve CV and pressure drops, list of control dampers, written sequences of operations, diagrams indicating panels, gauges, components, spring ranges, and setpoints, and complete composite wiring diagrams indicating all equipment interlocks for entire control system.

PART 2 - PRODUCTS

2.1 GENERAL PRODUCT DESCRIPTION

A. The building automation system shall consist of the following:

1. Stand-alone DDC panels.
2. Stand-alone application specific controllers (ASCs).
3. Personal computer operator workstation.
4. Portable laptop PC operator terminal.
5. DDC panel-mounted operator terminal.
6. Web addressable server

B. The system shall be modular in nature, and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, stand-alone DDC panels, and operator devices.

C. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC panel shall operate independently by performing its own specified control, alarm management, operator I/O, and historical data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

D. Stand-alone DDC panels shall be able to access any data from or send control commands and alarm reports directly to any other DDC panel or combination of panels on the network without dependence upon a central processing device. Stand-alone DDC panels shall also be able to send alarm reports to multiple operator workstations without dependence upon a central processing device.

2.2 NETWORKING/COMMUNICATIONS

A. The design of the BAS shall network operator workstations and stand-alone DDC panels.

B. Local Area Network:

1. Workstation/DDC Panel Support: Operator workstations and DDC panels shall directly reside on a local area network such that communications may be executed directly between controllers, directly between workstations, and between controllers and workstations on a peer-to-peer basis.
2. Dynamic Data Access: All operator devices shall have the ability to access all point status and application report data, or execute control functions for any and all other devices via the local area network.
3. General Network Design: Network design shall include the following provisions:

    a. High speed data transfer rates. The minimum transfer rate shall be 100 Mb (Mb/s).
    b. Commonly available, multiple source, networking components and protocols shall be used to allow the BAS to coexist with other networking applications. MAP, ETHERNET, IBM Token Ring and ARCNET are acceptable technologies.
    c. Use of an industry standard IEEE protocol.
    d. Synchronization of the realtime clocks in all DDC panels shall be provided.
    e. Permit at least four simultaneous users to access the system over the LAN, based on password level. Users shall have access to monitor parameters, change set points, set up trends, or start/stop controlled equipment. A remote user shall have this capability without having the system data base loaded on his/her remote computer.
    f. Paging/Email feature shall be provided with capability to telephone/email selected facility maintenance personnel to notify them of critical BAS alarms.

2.3 STAND-ALONE DDC PANELS

A. General: Stand-alone DDC panels shall be microprocessor based, multi-tasking, multi-user, real-time digital control processors. Each stand-alone DDC panel shall consist of modular hardware with plug-in enclosed processors, communication controllers, power supplies, and input/output modules.

B. Memory: Each DDC panel shall have sufficient memory to support its own operating system and databases.

C. Point Types: Each DDC panel shall support the following types of point inputs and outputs:

1. Digital Inputs for status/alarm contacts
2. Digital Outputs for on/off equipment control
3. Analog Inputs for temperature, pressure, humidity, flow, and position measurements

4. Analog Outputs for valve and damper position control, and capacity control of primary equipment
5. Pulse Inputs for pulsed contact monitoring

D. Expandability: The system shall be modular in nature, and shall permit easy expansion through the addition of software applications, workstation hardware, field controllers, sensors, and actuators.

E. Serial Communication Ports: Stand-alone DDC panels shall provide at least two RS-232C serial data communication ports for simultaneous operation of multiple operator I/O devices such as industry standard printers, laptop workstations, PC workstations, and panel mounted or portable DDC panel operator's terminals. Stand-alone DDC panels shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers, or network terminals.

F. Hardware Override Switches: The operator shall have the ability to manually override automatic or centrally executed commands at the DDC panel via local, point discrete, on-board hand/off/auto operator override switches for binary control points and gradual switches for analog control type points. These override switches shall be operable whether the panel is powered or not.

G. Hardware Override Monitoring: DDC panels shall monitor the status or position of all overrides and inform the operator that automatic control has been inhibited.

H. Local Status Indicator Lamps: The DDC panel shall provide local status indication for each binary input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device.

I. Integrated On-Line Diagnostics: Each DDC panel shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all subsidiary equipment.

J. Surge and Transient Protection: Isolation shall be provided at all network terminations, as well as all field point terminations to suppress induced voltage transients consistent with IEEE Standard 587-1980. Isolation levels shall be sufficiently high as to allow all signal wiring to be run in the same conduit as high voltage wiring where acceptable by electrical code.

K. Powerfail Restart: In the event of the loss of normal power, there shall be an orderly shutdown of all stand-alone DDC panels to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data, and battery back-up shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours. Upon restoration of normal power, the DDC panel shall automatically resume full operation without manual intervention.

L. Provide a battery backup (UPS) system to support DDC panel functions for a minimum of 15 minutes upon loss of power. The UPS system shall be provided regardless of connection to facility emergency power system.

2.4 SYSTEM SOFTWARE FEATURES

A. General:

1. All necessary software to form a complete operating system as described in this specification and on drawings shall be provided.
2. The software programs shall be provided as an integral part of the DDC panel and shall not be dependent upon any higher level computer for execution.

B. Control Software Description:

1. Pre-Tested Control Algorithms:

a. Two Position Control
b. Proportional Control
c. Proportional plus Integral Control
d. Proportional, Integral, plus Derivative Control
e. Automatic Control Loop Tuning

2. Equipment Cycling Protection.
3. Heavy Equipment Time Delays.
4. Powerfail Motor Restart.

C. Energy Management Applications: DDC panel shall have the ability to perform any or all of the following energy management routines:

1. Time of Day Scheduling
2. Calendar Based Scheduling
3. Holiday Scheduling
4. Temporary Schedule Overrides
5. Optimal Start/Stop
6. Night Setback/Setup Control
7. Economizer
8. Peak Demand Limiting
9. Temperature Reset

D. Custom Process Programming Capability: DDC panels shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.

E. Alarm Management: Alarm management shall be provided to monitor, buffer, and direct alarm reports to operator devices and memory files. Each DDC panel shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to noncritical alarms, minimize network traffic, and prevent alarms from being lost. At no time shall the DDC panel's ability to report alarms be affected by either operator activity at a PC workstation or local I/O device, or communications with other panels on the network.

F. Historical Data and Trend Analysis: A variety of historical data collection utilities shall be provided to automatically sample, store, and display system data in all of the following ways:

1. Continuous Point Histories.
2. Control Loop Performance Trends.
3. Extended Sample Period Trends.
4. Data Storage and Archiving.

G. Runtime Totalization: Stand-alone DDC panels shall automatically accumulate and store runtime hours for binary input and output points.

H. Analog/Pulse Totalization: Stand-alone DDC panels shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.

I. Event Totalization: Stand-alone DDC panels shall have the ability to count events such as the number of times a pump or fan system is cycled on and off.

2.5 APPLICATION SPECIFIC CONTROLLERS - HVAC APPLICATIONS

A. Each stand-alone DDC controller shall be able to extend its performance and capacity through the use of remote Application Specific Controllers (ASCs).

B. Each ASC shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each ASC shall be a microprocessor-based, multi-tasking, real-time digital control processor.

C. Each ASC shall have sufficient memory to support its own operating system and data bases.

D. The operator interface to any ASC point data or programs shall be through any network-resident PC workstation or portable operator's terminal connected to any DDC panel in the network.

E. Application specific controllers shall directly support the temporary use of a portable service terminal.

F. Powerfail Protection: All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the controller.

G. Battery Backup (UPS): UPS shall be provided to support ASC functions for a minimum of 15 minutes upon loss of power. The UPS system shall be provided regardless of connection to facility emergency power system.

H. The modes of operation supported by each ASC shall minimally include, but not be limited to, the following:

1. Daily/Weekly Schedules

2. Occupancy Mode
3. Economy Mode
4. Temporary override Mode

I. Continuous Zone Temperature Histories: Each ASC shall automatically and continuously maintain a history of the associated zone temperature to allow users to quickly analyze space comfort and equipment performance for the past 24 hours. A minimum of two samples per hour shall be stored.

J. Alarm Management: Each ASC shall perform its own limit and status monitoring and analysis to maximize network performance by reducing unnecessary communications.

K. Application Descriptions:

1. Unitary Controllers:

a. Unitary controllers shall support, but not be limited to, the following types of systems to address specific applications indicated on the drawings:

1) Heat Pumps
2) Packaged Rooftops
3) Fan Coils

b. Unitary controllers shall support the following types of point inputs and outputs:

1) Economizer Switchover Inputs
2) Drybulb
3) Outdoor Air Enthalpy
4) Differential Temperature
5) Differential Enthalpy
6) Binary Input from a separate controller
7) Economizer Outputs
8) Integrated Analog with minimum position
9) Binary output to enable self-contained economizer actuator
10) Heating and Cooling Outputs
11) 1 to 3 Stages
12) Analog Output with two-pipe logic
13) Reversing valve logic for Heat Pumps
14) Fan Output
15) On/Off Logic Control

2. AHU Controllers:

a. AHU controllers shall support all the necessary point inputs and outputs to perform the specified control sequences in a totally stand-alone fashion.
b. AHU controllers shall have a library of control routines and program logic to perform the sequence of operation.

2.6 OPERATOR INTERFACE

A. Command Entry/Menu Selection Process: Operator workstation interface software shall minimize operator training through the use of English language prompting, English language point identification, and industry standard PC application software.

B. The operator interface shall minimize the use of a typewriter style keyboard through the use of a mouse or similar pointing device, and "point and click" approach to menu selection. Users shall be able to start and stop equipment or change setpoints from graphical displays through the use of a mouse or similar pointing device.

C. Graphical and Text-Based Displays: At the option of the user, operator workstations shall provide consistent graphical or text-based displays of all system point and application data described in this specification. Point identification, engineering units, status indication, and application naming conventions shall be the same at all workstations.

D. Password Protection: Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display and data base manipulation capabilities as he deems appropriate for each user, based upon an assigned password.

E. Operator Commands: The operator interface shall allow the operator to perform commands including, but not limited to, the following:

1. Start-up or shutdown selected equipment.
2. Adjust setpoints.
3. Add/Modify/Delete time programming.
4. Enable/Disable process execution.
5. Lock/Unlock alarm reporting for each point.
6. Enable/Disable Totalization for each point.
7. Enable/Disable Trending for each point.
8. Override PID Loop setpoints.
9. Enter temporary override schedules.
10. Define Holiday Schedules.
11. Change time/date.
12. Enter/Modify analog alarm limits.
13. Enter/Modify analog warning limits.
14. View limits.
15. Enable/Disable Demand Limiting for each meter.
16. Enable/Disable Duty Cycle for each load.

F. Logs and Summaries: Reports shall be generated automatically or manually, and directed to either CRT displays, printers, or disk files. Summaries shall be provided for specific points, for a logical point group, for a user-selected group of groups, or for the entire facility without restriction due to the hardware configuration of the building automation system. Under no conditions shall the operator need to specify the address of hardware controller to obtain system information.

G. Dynamic Color Graphic Displays: Color graphic floor plan displays, and system schematics for each piece of mechanical equipment shall be provided to optimize system performance analysis and speed alarm recognition.

H. Graphics Generation Package: Graphic generation software shall be provided to allow the user to add, modify, or delete system graphic displays.

I. System Configuration and Definition: All temperature and equipment control strategies and energy management routines shall be definable by the operator. System definition and modification procedures shall not interfere with normal system operation and control.

1. The system shall be provided complete with all equipment and documentation necessary to allow an operator to independently add/delete/modify all functions.
2. Programming Description: Definition of operator device characteristics, DDC panels, individual points, applications, and control sequences shall be performed through fill-in-the-blank templates and graphical programming approach.
3. System Definition/Control Sequence Documentation: All portions of system definition shall be self-documenting to provide hardcopy printouts of all configuration and application data. Control process and DDC control loop documentation shall be provided in logical, graphical flow diagram format to allow control sequences to be easily interpreted and modified at any time in the future.

2.7 PERSONAL COMPUTER OPERATOR WORKSTATION

A. General: Provide an operator's workstation to access the BAS network.

B. Provide PC Compatible computer system, Dell Inc. or approved equal with the following features:

1. 3.2 GHz Intel i7 equivalent processor.
2. 12 GB RAM memory minimum.
3. 500 GB hard drive.
4. Four USB ports built-in.
5. 48X CDRW/DVD combo drive.
6. 30" LCD color monitor.
7. USB Optical mouse.
8. USB keyboard.
9. Software: Windows 11

C. Provide a color ink jet printer for printing of alarms, graphics and any other screen displays.

D. Network Connection: Graphical workstations shall allow for access to the BAS network through a pull-down menu approach using only a mouse. The keyboard shall be required only when entering text or for programming functions. The workstation shall be used as an interface to the BAS network and shall not be required to process any control or energy management algorithms nor manage any BAS network communications.

E. Provide context-sensitive help menus to provide instructions appropriate with operations and applications currently being performed.

F. Multiple user security levels shall be provided to allow for various degrees of system access and control. The system shall automatically generate a report of log-on/log-off time and system activity for each user. Provide automatic log-off capability to prevent unauthorized system use.

G. The workstation shall be provided with a key element display that records log-ons, log-offs, overrides, alarms and alarm acknowledgments.

2.8 PORTABLE LAPTOP PC OPERATOR TERMINAL

A. Furnish one Portable Laptop PC Operator's Terminal and software to be used for communication with any controller. The terminal shall be a Windows Vista Business edition based laptop personal computer that uses controller interface software to communicate with the controllers. Manufacturer shall be Dell, Inc. or approved equal.

B. When plugged into any controller on the BAS network, the portable terminal shall have the same functionality as a stationary terminal with full editing, programming, display, and command functions. The terminal shall allow access to the entire network.

C. The terminal shall have minimum 3.0 GHZ Intel i7 processor, 4.0 GB RAM internal memory, built-in 250 GB hard drive and 48X CDRW/DVD Combo drive. In addition, the terminal shall have two USB ports Nic-Ethernet.

2.9 STAND-ALONE DDC PANEL-MOUNTED OPERATOR'S TERMINAL

A. Each DDC panel shall include a local panel-mounted operator's terminal for local command entry, instantaneous and historical data display, setpoint adjustment and program additions and modifications.

1. The DDC panel operator terminal shall provide access to all real or calculated points in the controller to which it is connected or any other controller in the network.
2. Operator access at all DDC panel operator terminals shall be identical to each other, as well as identical to the PC operator workstations. Any password changes shall automatically be downloaded to all controllers on the network.

3. The DDC panel operator terminal shall provide English language prompting to eliminate the need for the user to remember command formats or point names.
4. A multi-function touchpad shall be provided for point and command selection, as well as parameter entry.
5. Context-Sensitive Help.
6. Identification for all real or calculated points shall be consistent for all network devices. Use English language names to access points at the DDC panel operator's terminal.
7. In addition to instantaneous summaries, the DDC panel operator's terminal shall allow a user to view a point history file for system points.

2.10 ELECTRONIC, ELECTRIC AND PNEUMATIC CONTROL COMPONENTS

A. All sensors, pressure transmitters, transducers, etc., shall be selected such that the pressure range midpoint shall coincide with the anticipated normal operating pressure.

B. Electric Thermostats: Thermostats to be manufacturer's best commercial grade thermostat with adjustable setpoint, dials calibrated in degrees F, and digital temperature indication. Select thermostats with suitable range for service intended. Temperature measurement accuracy shall be +/- 0.5 degrees F. Thermostats located in public areas such as corridors shall be provided with programming lockout to prevent unauthorized adjustment. Thermostats located where subject to physical damage and/or where identified on drawings shall be provided with tamper resistant cover. Warmer – Cooler setpoint adjustment will not be acceptable.

C. Electronic Sensors/Transmitters: Sensors/transmitters to be 1000 Ohm platinum RTD type with high resistance change vs. temperature or humidity change, accurate to +/- 0.3 degrees F for temperature and +/- 2.0% for humidity at applicable range, and provide 4 to 20 MA or 0 to 5 VDC output signal. Sensors/transmitters to be suitable for room, duct, or well mounting as required by application. Room type to have built-in setpoint potentiometer and digital room temperature or humidity indication. Select for temperature/humidity range of application. Provide appropriate mounting plate and hardware. Temperature sensors used as a part of Energy (BTU) Measurement System shall meet the applicable requirements of that section. Sensors shall have setpoint adjustment through BAS only. Sensors located where subject to physical damage and/or where identified on drawings shall be provided with protective cover. Provide these devices where identified on the contract documents or if not shown on design documents provide at all locations listed within this section. Humidity sensors are to be stand-alone sensors and at a minimum provided within each data hall row.

D. Smoke Detectors: Install duct-mounted smoke detectors at locations indicated on drawings and in accordance with published smoke detector installation requirements. Smoke detectors to be furnished to Division 23 by Division 26.

E. Freezestats (Low Limit Binary Type): Provide single, custom length Freon-filled capillary tube type with sensing element actuated by temperature on any one foot portion. Sensor shall be a single element with length of one linear foot for every one square foot of coil face area. Freezestats to be UL approved, manual reset type.

F. Averaging Temperature Sensors (Mixed Air, Preheat, Etc.): Provide single, custom length Freon-filled capillary tube type sensing element. Accuracy shall be +/- 0.3 degrees F. Sensor shall be single element with length of one linear foot for every one square foot of coil face area.

G. Control Panels: Control panels to be constructed of unitized steel or aluminum cabinets. Provide cabinets with hinged, locking door opening to the front. Multiple panels mounted side-by-side to be hinged to the left or on opposite sides to open in the middle. Start-stop switches, hand-off-automatic switches, pilot lights, and temperature indicating devices to be flush-mounted in panel door. All other devices to be internally mounted within panel. Local panels exposed to weather to be weatherproof construction. Panel locations to be approved by Designer and be accessible for operation and maintenance. All devices specified to be mounted on control panel that require electrical connections to be prewired to a dual, numbered terminal strip located inside panel. Pneumatic piping inside panel may be poly properly supported in laced bundles or in panduit trays. All lines in panel shall have number I.D. bands. Gauges shall be installed on all pneumatic lines entering or leaving the panel. All devices inside the panel or mounted on panel face shall have an engraved laminated plastic nameplate. Wiring within panel to conform to National Electrical Code, and shall be neatly bundled and laced or enclosed in panduit trough.

H. Control Valves: Two-inch and smaller water service valves to be screw connected chrome plated brass ball type with characterized port to allow equal percentage throttling. Two-and-one-half inch and larger to be flange connected, brass-body ball-type with ductile iron flanges and stainless steel trim. Valve pressure rating to be in accordance with piping and fitting specification Section 23 21 13. (Minimum 125 psi operating pressure.) Provide pilot positioning relays for pneumatic operated valves requiring sequencing except at terminal units. Valve actuators to be selected to close valves against pump shutoff head or maximum steam inlet pressure. Provide stainless steel stem with removable composition disc and self adjusting spring-loaded Teflon packing. Two position water valves to be line size or one line size smaller than connecting piping with maximum 1 psi water pressure drop. Modulating water valves to have equal percentage flow characteristics and be sized for maximum 4 psi water pressure drop. Zone type, tri-state, pulse type, or similar non-proportional control valves/actuators are <u>not</u> acceptable.

I. Automatic Control Dampers: Ultra low-leak automatic control dampers to be Arrow Pin Lock opposed-blade dampers for modulating control and parallel blades for 2-position control or approved equal. Frames and blades to be minimum 16 gauge extruded aluminum or galvanized steel construction with 4" to 6" deep frame and 8" maximum width blades. Pivot rods to be 1/2" diameter, extruded aluminum or plated steel. Bearings to be corrosion resistant. Install blade linkage hardware in angle or channel frame section out of airstream. All hardware to be corrosion resistant. Seals to be replaceable extruded vinyl or silicone rubber blade seals and flexible metal compression type jamb seals. Dampers to have maximum 4 cfm per square foot leakage at 1" water gauge static pressure and 8 cfm per square foot leakage at 4" water gauge static pressure, verified by independent testing laboratory.

J. Electronic Actuators: Actuators shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator. End switches to deactivate the actuator at the end of rotation or magnetic clutch is not acceptable. For power-failure/safety applications, a mechanical, spring return mechanism shall be used. Non-mechanical forms of fail-safe are not acceptable. All spring return actuators shall be capable of both clockwise or counterclockwise spring return operation by changing mounting orientation. Proportional actuators shall accept a 2 to 10 VDC or 4 to 20 mA and provide a 2 to 10 VDC position feedback signal. 24 VAC/DC actuators shall not require more than 15 VA for AC or 8 watts for DC applications. All non-spring return actuators shall have an external manual gear release to aid in installation and allow manual positioning when the actuator is not powered. All actuators shall have an external direction of rotation switch to aid in installation and provide proper control response. Actuators shall be provided with a factory-mounted 3-foot electrical cable and conduit fitting to provide easy hook-up to an electrical junction box. Provide cover mounted control transformer for 120-VAC power supply. The actuators shall be U.L. listed.

K. Volumetric Devices: Fan Inlet Air Flow Sensors and Indicating Transmitters

1. Fan Inlet Piezometer Air Flow Sensors shall be factory mounted in the air handling units. They shall be piezometer type average velocity sensors designed for installation inside the inlet ring of centrifugal fans accurate to +/- 1.5% measurement accuracy. There shall be no portions of device protruding into inlet cone.

2. Air flow transmitters shall be field installed by the controls sub-contractor. The airflow transmitter shall be an industrial quality, electronic solid state, ultra low span, ½ percent accuracy transmitter with integral square root, scaling, and output filter with indication. Each transducer shall be provided with a microprocessor digital readout meter, operating independent of all other control devices. This unit to provide a direct digital readout of the air volume as derived from the total and static input signals received from the respective air flow measuring element. The meter shall have a digital readout and 3 way zeroing valve for zero verification and calibration. Readout to be flush mounted on the enclosure door. The meter shall be calibrated to an accuracy of +/- 2% of span. Area factor input for respective inlet probes to be adjustable via a keypad. Provide individual airflow transmitters, especially selected for the required spans of each of the above primary processor shall to be Paragon Controls Inc. Model MT-1.
3. For Air Handling Units with 2 or more supply fans AND 2 or more return fans, the transmitter shall be Paragon Controls, Inc. FAATS-1000 fan array airflow totaling system. Output signal shall be 4-20mA and shall measure airflow for each individual fan within a fan array system as well as the total airflow rate of each array.

L. Water Flow Meters:

1. Water flow meters shall be installed in strict accordance with manufacturer's instruction and with minimum upstream and downstream straight length as required for specified measurement accuracy.
2. For chilled water and hot water applications in pipe sizes 3" to 72" the flow meter construction shall be 316 stainless steel wetted metal components with polypropylene sensing head, insertion type suitable for 400 psi pressure and 15 to 250 degree F temperature. Provide ball type isolation valve and all necessary installation hardware to enable insertion and removal of the meter without system shutdown. The flow meter shall be hand-insertable up to design pressure. Meter accuracy shall be within ± 1.0% of rate between flow velocities of 2 to 20 feet per second and +/- 0.02 ft/s at 0.25 ft/s to 2 ft/s. Meter flow range shall be 0.25 ft/s to 20 ft/s (80:1 turndown). Output signal shall be selectable: 4-20mA, 0-10 V or 0-5 V. Water flow meter shall be Onicon Model F-3500 Insertion Electromagnetic Flow Meter. McCrometer, Inc. Multi-Mag or Ultra-Mag selected for application shall be acceptable as an alternate.
3. Bi-directional meters shall be the Onicon FB-1210 Insertion Dual Turbine Meter and shall include an isolated contact closure output for direction. Bi-directional flow meter shall be utilized where flow meter is indicated in chilled water bypass or elsewhere as indicated on drawings. Meter accuracy shall be within ± 0.5% of reading at the calibrated velocity, maximum +/- 1.0 percent of reading between flow velocities of 3 to 30 feet per second 10:1 and +/- 2.0% of reading at 0.4 ft/s to 20 ft/s 50:1. Output signal available are 4-20mA or 0-10 V. Water flow meter shall be Onicon Model F-1210 Insertion Dual Turbine Flow Meter.

M. Energy (BTU) Measurement System:

1. The entire Energy Measurement System shall be provided by a single manufacturer, and shall consist of a water flow meter, two temperature sensors, a BTU meter, temperature thermowells, and all required mechanical installation hardware. A certificate of calibration shall be provided with each system. The BTU meter shall provide the following points both at the integral LCD and as outputs to the building control system: Energy Total, Energy Rate, Flow Rate, Supply Temperature and Return Temperature. Output signals shall be serial network (protocol conforming to BACnet MS/TP, LONWORKS, JCI-N2 or Siemens-P1 as required by controls manufacturer). Each BTU meter shall be factory programmed for its specific application, and shall be re-programmable using the front panel keypad (no special interface device or computer required). BTU meter shall be Onicon System-10 BTU Meter.
2. Temperature Sensors: Temperature sensors shall be loop-powered current based (mA) sensors and shall be bath-calibrated and matched for the specific temperature range for each application. The calculated differential temperature used in the energy calculation shall be accurate to within $\pm$0.15 degrees F (including the error from individual temperature sensors, sensor matching, input offsets, and calculations).

N. Water Flow Meters: Provide insertion type electromagnetic water flow meter as specified elsewhere in this section of the specifications.

O. Static Pressure Devices: Static pressure measuring stations with +/- 2% accuracy equal to Paragon Controls PE-5000 shall be provided. Industrial quality, electronic solid state, 1/2 percent accuracy static pressure transmitters equal to Paragon Controls Model DPT-4001 shall be provided. Transmitter span shall be matched to application.

P. Transformers: Provide all 24-volt control transformers necessary to convert 120-volt line voltage power to control voltage at control devices.

Q. Relays, Hand-Off-Auto Switches, Pilot Lights: Provide all relays, hand-off-auto switches, and pilot lights necessary to accomplish automatic control of the mechanical systems. See electrical drawings for starters provided integral with hand-off-autos, pilot lights, and auxiliary contacts.

R. Pressure Switches: Pressure switches shall have contact action and pole configuration as required by application, U.L. listing, and adjustable setpoint.

S. Current Sensing Relays:

1. Acceptable Manufacturer: Hawkeye Model 908 or approved equivalent.
2. Current sensor shall be induce powered from the monitored load and shall have an adjustable operating range from 2.5 - 135 A. Visual indicators (LEDs) shall indicate output status and sensor power. Adjustable trip setpoint to +/- 1%. Current sensor output shall be N.O., solid state, 0.1A @ 30 VAC/DC.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Components:

1. Provide sensors, transmitters, controllers, actuators, valves, dampers, and related items, necessary to accomplish control sequence shown on drawings. Install all such devices except as noted herein to the contrary.
2. Deliver control valves to the job site to be installed by Mechanical Tradesman under supervision of Control Tradesman.
3. Deliver automatic dampers to the job site to be installed by Mechanical Tradesman under supervision of Control Tradesman.
4. Mechanical Tradesmen to install flow switches, immersion wells, pressure tapping, and all associated shut-off cocks required for control systems.
5. The control equipment and connecting piping shall be installed in a neat and workmanlike manner by trained mechanics in the direct employ of the control manufacturer.
6. All exposed tubing and conduit shall be run parallel to or at right angles to the building structure, and shall be concealed in all finished spaces. Tubing and conduit may be run exposed in mechanical rooms or areas where other piping is exposed.
7. Prepare coordinated composite wiring diagram showing all interlock wiring associated with starters, control panels, and controls.
8. Drawings and Layouts: The controls contractor shall provide to the mechanical contractor complete schematic drawings for the entire control system for submittal to the Designer for approval before work shall begin. Brochures describing each item of control equipment or component shall be included.
9. Provide sequence of operation written so that building engineer can read and understand control scheme.
10. As-built drawings to be framed under plexiglass and placed in each respective equipment room area.

B. Electrical:

1. Contractor shall furnish and install low-voltage control wiring, including conduit, conductors, and terminations for same. Division 23 shall also furnish and install control components associated with the low-voltage control systems and shall wire and connect components in accordance with approved wiring diagrams.
2. Division 26 Electrical Tradesman shall furnish and install power wiring including conduit, conductors, and terminations to motors, safety switches, starters, relays, valve and damper actuators, and other components requiring power as indicated on the electrical drawings, by the specifications, and in accordance with approved wiring diagrams. Division 26 shall also furnish and install starters as scheduled on the electrical drawings.

3. Contractor to furnish and install all local area network wiring, including conduit, conductors, and terminations for same. The local area network (LAN) shall be configurable as either a bus or a star, or a combination of the two. The LAN shall use twisted pair, coax, or fiber optic cable, or any combination of the three to meet noise immunity and/or distance requirements. The network design shall provide a high speed data transfer rate for alarm and report generation of no less than 100 Mb (Mb/s).
4. Contractor to furnish all input and output control wiring, including conduit, conductors, and terminations for same. All input and output control wiring shall be #18 twisted and shielded cable. No input or output point shall be more than 250 feet from its respective panel. All shields to be grounded at the control panel. All shields at the sensors or transducers to be folded back and taped. All cable splices shall have joints soldered and taped including the shield. No mechanical connections will be acceptable. All connections within the panels must be made with connectors of appropriate size and design for the terminals being applied. All cables must be labeled and identified on corresponding termination drawings. A copy of the termination drawing shall be adequately protected and left in its respective panel.
5. Install all control wiring associated with DDC/BAS in minimum 1/2" size EMT. Provide all associated couplings, connectors, and fittings. No electrical wiring and polyethylene tubing may occupy the same conduit. Separate carriers are required.
6. All wiring shall be in accordance with local regulations and the National Electrical Code.

C. Room Devices:

1. Room devices shall be mounted so that the top of the device is 48" above the floor and aligned with the top of the light switch plates and 8" from the light switch if shown on the drawings adjacent to the light switch.
2. Room device locations shall be coordinated with door swings, light switches, and other wall-mounted items.

D. Pressure/Temperature test ports shall be installed on the entering and leaving side of all heat transfer coils, heat exchangers (HVAC and domestic, both hot and cold fluid), control valves, flow meters, pumps, etc. Installation of P/T ports will facilitate the "Sensor Calibration Check" phase of the functional performance testing (FPT).

E. The contractor shall provide Tee type connections (and associated stop cocks or caps) in the pressure sensor tubing at all differential pressure sensors, including ductwork static pressure, high static pressure, airflow measuring devices, hot and cold water differential pressure, etc., that will allow field test measurements to be taken without interrupting the BAS reading. Providing this type connection will facilitate the sensor calibration check phase of functional performance testing and maintenance, by allowing simultaneous comparison of the BAS reading versus the actual field-measured parameter.

F. Calibrated balancing valves, flow elements and meters shall be installed in strict accordance with the manufacturer's recommendations for orientation, required straight length of upstream and downstream piping, etc., and in no case shall the pressure ports be pointed downward, in order to prevent the accumulation of trash and debris inside the ports. The ports shall be installed in such a manner that allows unobstructed access for the TAB agency to plug into the ports for purposes of measuring and verifying the differential pressure of the valve.

3.2 QUALITY CONTROL

A. Control system to be set up and checked out by factory-trained competent technician skilled in the setting and adjustment of temperature controls used in this project. This mechanic to be experienced in type systems associated with this control system.

B. At time of final observation, Control Contractor to demonstrate the entire sequence of operation for the systems to the Engineer. At this time, Engineer to observe function of entire control system, observe temperature control operations, damper positions, necessary to assure that temperature control system is operating as intended by mechanical design.

C. Final acceptance of system not to occur until sequence of operation check has taken place and certified by Engineer's representative.

D. The Control Tradesman to be responsible for returning to job during the opposite season to verify operation of control system. Engineer to be given notice of this return and to accompany Control Tradesman to observe the sequence of operation.

3.3 INSTRUCTION AND ADJUSTMENT

A. On completion of the job, the controls contractor shall have completely adjusted the entire control system. He shall arrange to instruct the Owner's representative on operation of the control system and supply him with three (3) copies of the control operating and instruction manuals.

B. The Controls Contractor shall obtain from the Owner's representative a signed receipt that he has received the instruction manuals and complete instruction on the operation of the system.

C. Contractor Adjustment: At the completion of the job, the controls contractor must submit to the Architect a letter stating that he has made final calibrations and adjustments to the system and that the Owner's operating personnel have been instructed in its use.

3.4 WARRANTY SERVICE

A. Warranty servicing shall be for a period not less than 12 months after final acceptance of the job by the owner and include the following provisions:

1. Emergency maintenance service on regular working hour basis during warranty.
2. Replacing defective parts and components as required.
3. Servicing by factory trained and employed service representatives of system manufacturer.
4. Maintaining of system programming.

END OF SECTION 23 09 23

SECTION 23 21 21 - END-SUCTION, FLEXIBLE COUPLED PUMPS

PART 1 GENERAL

1.1 WORK INCLUDED

A. Pump to be, single-stage, end suction, horizontally frame-mounted, flexible coupled, bronze fitted, centrifugal type pump driven by single-speed, squirrel-cage motors.

B. Pump manufacturer shall furnish and be responsible for the selection, compatibility, and performance of each unit consisting of pump, motor, coupling, and base plate.

C. Pumps to be Taco FI Series or approved equal.

D. NOTE: Motor horsepower indicated on schedule to allow non-overloading operation of pump. Pumps requiring larger motors will not be acceptable. Exceptions for smaller motors used in combination with current limiting VFDs can be submitted for approval by Design Engineer.

E. Pumps shall not be selected requiring impeller sizes within 10 percent of maximum impeller size for that pump size and/or have an efficiency of 75 percent or less.

PART 2 PRODUCTS

2.1 PUMP

A. Construct pump casing of high-grade cast iron structurally designed for the working pressure and temperature shown on drawings. Hydrostatically test casing at one and one-half times the design working pressure.

B. Pump casing to have gauge ports at suction and discharge, and vent and drain ports at top and bottom of casing.

C. Pump to include back-pullout design to permit fast, easy access for servicing pump without disturbing suction or discharge piping.

D. Pump volute to be solidly mounted to base through a pedestal support.

E. Impeller to be bronze and of enclosed type. Impeller to be dynamically balanced and key-locked to the shaft.

F. Shaft to be carbon steel designed for minimum deflection (not to exceed 0.002") at sealing faces at maximum load.

G. Provide grease-lubricated ball bearings in housings sealed to exclude moisture and dirt. Bearings to include design features that positively prevent over-lubrication.

H. Provide replaceable bronze casing wearing rings to provide proper running clearance.

I. Pump to be furnished with mechanical seal with all metal parts 303 stainless steel with Buna-N Elastomers, Ni-Resist seat, and carbon washer. Unit to be equipped with bronze key-locked shaft sleeve extending full length of seal box.

2.2 COUPLING AND BASE PLATE

A. Manufacturer to furnish and mount pump and motor on common steel base plate with drip rim.

B. Manufacturer to furnish and mount flexible coupling. Fasten metal coupling guard to pump base plate.

C. Nameplate: Provide pump and motor with stainless steel or aluminum nameplate securely fastened to casings. Nameplates to provide all data necessary for equipment identification and replacement.

PART 3 EXECUTION

3.1 INSTALLATION

A. Provide pumps with soleplates, bedplates, or base plates carefully leveled, grouted, and bolted in place on concrete pads or foundations. Grout to be expanding type containing catalyzed metallic aggregate. After grout has set, cut flush with bedplate and seal to prevent fraying deterioration at edges.

B. Make hot alignment check on couplings between motors and pumps. Operate equipment until components have reached operating temperature before hot check is made. Reposition equipment as required and repeat hot alignment check until parallel and angular alignments in both plan and elevation are within limits set by equipment manufacturer.

C. Provide Suction Diffusers on each pump.

END OF SECTION 23 21 21

SECTION 23 22 01 – PROCESS PIPING SYSTEMS

PART 1 - GENERAL

1.1 WORK INCLUDED

A. The work included under this section of the specifications consists of the basic materials and methods and is applicable to all process piping work done under Division 23.

B. The Contractor shall provide all materials, tools, equipment and labor to install all piping systems illustrated on the design drawings and specified herein. The specifications for piping systems not specified on the design drawings or elsewhere herein are provided on schedules at the end of this Section.

C. This section prescribes the minimum requirements for materials, fabrication, erection, test and inspection of pipe, flanges, bolting, gaskets, valves, fittings, and all piping accessories shown on the contract drawings or otherwise required to make a complete and operable system. All piping subject to ASME code shall satisfy the requirements of the ASME code. All process piping shall satisfy the requirements of ASME B31.9 Building Services Piping Code for the working pressure and service temperature involved. All valves, fittings, flanges and unions shall be marked according to MSS-SP-25 standards.

D. The size of all pipe is identified by the nominal pipe size. All references to wall thickness, schedule numbers, and weights are defined by ANSI B36.10. Variations in pipe dimensions and tolerances shall not exceed ASTM Specification for each pipe material specified herein.

E. All materials are to be new and unused and clearly marked with the manufacturer’s name, weight and classification of working pressure.

1.2 RELATED SECTIONS

A. Section 23 21 20 – Hydronic Specialties

B. Section 23 07 10 - Insulation

1.3 SUBMITTALS

A. Submit manufacturer's data for all pipe, valves, fittings and other system components specified herein. Submittals may be in electronic form or six hard copies. Contractor must signify by stamp and signature or similar means that he has reviewed the products for conformance to the specifications and drawings. Clearly note on all vendor information what service the product is applicable to and which of the vendor options are selected.

B. Submit Welding Procedure Specifications (WPS) for every welding procedure to be used. Qualification for each welding procedure shall conform to the requirements of ASME B31.9. The method for each system shall be fully described including the number of beads, volts, amperes, and the welding rod for various pipe wall thicknesses and materials. The welding procedures shall specify end preparation for butt welds including cleaning, alignment, and root openings. Pre-heat, interpass temperature control, and post-heat treatment of welds shall be as required by approved welding procedures, unless otherwise indicated or specified. Approval of any procedure does not relieve the Contractor of the sole responsibility for producing acceptable welds. Welding procedures shall be identified individually and shall be clearly referenced to the type of welding required for this project. These procedures shall be the same as those used for all pipe welder qualification tests, all shop welds, and all field welds. The Contractor shall provide Procedure Qualification Records for all proposed Welding Procedure Specifications (WPS).

C. Submit Welder Performance Qualifications (WPQ) for each welder for each weld type he/she will perform. Provide WPQs using ASME Form E00008, QW-484- "Suggested Format for Manufacturer's Record of Welder or Welding Operation Qualification Test (WPQ)". If the qualification test for any welder is more than 6 months old, provide record of welding continuity for those welders. Continue to submit WPQs as welders are added to the project throughout the job.

D. Submit an administrative procedure for recording, locating, monitoring, and maintaining the quality of welds to be performed on the project. The quality control documents shall include documents (drawings, schedules, etc.) identifying location of each weld by individual number, identification of welder who performed each weld by individual welder's name, stamp number, date, and WPS used.

1.4 REFERENCES

A. American National Standards Institute (ANSI)/American Society of Mechanical Engineers (ASME)

1. ASME B31.9 - Building Services Piping
2. ANSI/ASME B1.20.1 - Pipe Threads
3. ANSI/ASME B16.21 – Nonmetallic Flat Gaskets
4. ANSI/ASME B16.25 - Buttwelding Ends
5. ANSI/ASME B16.3 - Malleable Iron Threaded Fittings
6. ANSI/ASME B16.9 - Factory-Made Wrought Steel Buttwelding Fittings
7. ANSI/ASME B16.5 - Pipe Flanges and Flanged Fittings
8. ANSI/ASME B16.11 – Forged Fittings, Socket-Welding and Threaded
9. ANSI/ASME B36.10M - Welded and Seamless Wrought Steel Pipe
10. ANSI/ASME B46.1 – Surface Texture (Surface Roughness, Waviness, and Lay)
11. ANSI/ASME A 13.1 – Scheme of the Identification of Piping Systems

B. Manufacturer's Standardization Society of the Valves and Fittings Industry (MSS)

1. MSS-SP-25 - Standard Marking System for Valves, Fittings, Flanges and Unions

2. MSS SP-44 - Steel Pipeline Flanges
3. MSS SP-58 - Pipe Hangers and Supports - Materials, Design, and Manufacture

C. American Welding Society (AWS)

D. American Society of Testing Materials (ASTM)

1. ASTM D2657
2. ASTM D4024
3. ASTM F2389

E. International Mechanical Code (IMC)

F. State of Colorado

1.5 APPLICABLE CODES

A. The applicable code for each piping system is identified in the schedules provided at the end of this Section.

B. The following codes are ANSI/ASME codes and all materials, fabrication, installation, documentation, and testing of each piping system shall meet all of the requirements of the specified code for the location, pressure, and temperature ratings for the piping system, and all other requirements specified herein.

1. ASME B31.9

C. The following codes are not ANSI/ASME codes and all piping systems for these codes shall be fabricated, installed, documented, and tested in accordance with the requirements specified herein.

1. General Service
2. Sanitary

1.6 QUALITY ASSURANCE

A. All materials are to be new and unused and clearly marked with manufacturer's name, and classification of working pressure.

B. Welder Performance Qualifications (WPQ) shall have been performed under the witness of an independent testing agency and shall have undergone radiographic examination (i.e., only x-ray qualified welders shall be acceptable). The weld examiner shall be a representative of an independent testing agency, an Authorized Inspector, or a consultant, any of which must be approved by the National Certified Pipe Welding Bureau or by the American Society of Nondestructive Testing (ASNT).

PART 2 - PRODUCTS

2.1 STEEL PIPE AND VALVES

A. Materials and basic industry specifications for piping, fittings, flanges, valves, etc., are described on schedules at the end of this section. These requirements are to be interpreted as minimum standards for the service specified. In case of conflict between these schedules and written paragraphs of this specification, the written paragraph shall govern. Wherever an industry specification or standard is shown for a size or type not covered by that standard, the intent of the industry standard shall apply. Piping to be manufactured in USA.

B. Pipe materials and type of fittings, valves, gaskets, etc., shall be for the service in which the piping is installed and not less than the quality established in the schedules presented herein.

C. All piping shall be stenciled as to its ASTM type, grade and weight.

D. This specification shall govern for all pipe, valves, fittings, accessories, etc., not specifically noted on the drawings.

2.2 STEEL PIPE FITTINGS

A. Fittings shall be as manufactured by Anvil, Crane Midwest, Tube Turn, Taylor Forge, Bonney Forge, Tri-Clover, Ladish, Nupi Americas, or equivalent.

B. All fittings shall be compatible with the pipe material, working pressure and service temperature of the system in which they are being used.

C. Forged flanges and fittings to be factory-forged in USA and shall not have been machined, remarked, painted, or otherwise produced domestically from non-domestic forgings.

D. Flanges, fittings, unions and other products recognized as regularly available products to be marked in accordance with MSS SP-25.

E. Plastic-to-Metal Transition Fittings:

1. Source Limitations: Obtain plastic-to-metal transition fittings from single manufacturer.
2. Description:

    a. One end with threaded brass insert and one solvent-cement-threaded end.

3. One-piece fitting with one threaded brass or copper insert and one solvent-cement-joint end of material and wall thickness to match plastic pipe material.

F. Dielectric unions shall be used when joining pipe of dissimilar metals.

G. Plastic-to-Metal Transition Unions:

a. Source Limitations: Obtain plastic-to-metal transition unions from single manufacturer.
b. Brass or copper end and solvent-cement-joint end of union to match pipe in size and material.
c. Description:

1) Brass threaded end.
2) Solvent-cement-joint or threaded plastic end.
3) Rubber O-ring.
4) Union nut

H. All flanges mating with cast-iron and/or PP flanges shall be flat faced.

I. All ell fittings shall be long-radius or as noted otherwise on the design drawings.

2.3 VALVES

A. Valves shall be as listed in the schedules included herein or approved equal. All valves shall be rated for the listed service, temperature, and pressure, and shall have end connections as specified in the schedules.

2.4 JOINTS

A. Threaded joints shall be joined using Crane "Formular 425" thread lubricant or approved equal. As an option, the Contractor may use an approved Teflon tape for threaded connections.

B. Polypropylene pipe shall be joined by low voltage fusion welding or mechanical joint.

2.5 NIPPLES

A. All steel pipe nipples shall be galvanized or black, minimum Schedule 40 and match pipe size. All nipples to be used in conjunction with copper pipe to be brass.

2.6 BOLTING

A. Studs, bolts and nuts shall be as specified for each system except where flanges of different materials (i.e., cast-iron to steel) are joined together. In this case, only carbon steel (without heat treatment) bolts and nuts may be used, such as ASTM A-307 Grade B or as otherwise allowed by MSS SP-46.

2.7 HANGERS AND SUPPORTS

A. Provide all hangars, supports, rods, shields, saddles, anchors, guides, supplementary steel, and special appurtenances required for proper support of all piping included in this specification, and as shown on the design drawings.

B. Provide all concrete inserts, expansion shells, anchor bolts, expansion anchors, insert nuts, etc., as required for attaching hangers and/or supports to the building structure, as shown on the design drawings.

C. Use commercially available load-rated and tested components wherever possible, as shown on the design drawings and as specified herein.

D. Auxiliary supporting steel shall be designed on the basis of the allowable stresses in accordance with the AISC Steel Handbook.

E. Rolled steel W shapes shall conform to ASTM A992, 50 ksi minimum yield strength, unless noted otherwise on drawings. ASTM A572, grade 50 may be substituted for ASTM A992.

F. Rolled steel M, S, HP, C, MC, and L shapes, plates and bars shall conform to ASTM A36, 36 ksi minimum yield strength unless noted otherwise on drawings.

G. All steel in contact with alloy steel piping shall be fabricated from suitable steel alloy material (e.g., ASTM A387 Gr 11 / ASTM A335 Gr P11).

H. All piping shall be carried on adjustable hangers or properly leveled supports. All parts shall be fabricated and assembled so that they will not be disengaged by movement of the supported piping. Screws or equivalent adjustments shall be provided with suitable locking features.

I. Where piping is to be hung from the building structural steel, hangers shall be attached by means of C-clamps or beam clamps, for the specific loads, as manufactured by Anvil, Elcen, Fee & Mason, or approved equal. Welding of hanger rods to building steel will not be permitted, nor drilling or burning holes in building steel, unless specifically detailed on the drawings.

J. All upper support attachments where piping is hung from steel shall be universal beam clamps with weld-less eye nut, galvanized finish, Anvil Figure 292, MSS-SP-69 Type 28 or 28, or welded bean attachment, galvanized finish, Anvil Figure 66, MSS-SP-69 Type 22, or C-clamp with set screw and retaining clip, galvanized finish, Anvil Figure 87, MSS-SP-69 Type 23, or approved equal.

K. Unless detailed otherwise on the design drawings, where piping supports are hung below concrete, supports shall be anchored with concrete inserts or ceiling anchor bolts. The size of all concrete inserts and anchor bolts shall be adequate for the imposed loads to the support to support the piping, valves, etc., when full of water and the piping system is in operation at its normal service temperature. The location of concrete inserts and anchor bolts shall be coordinated with the placement of concrete and structural embeds. Provide concrete inserts and ceiling anchor bolts as follows.

1. Piping 8 inches and smaller: Universal concrete inserts, galvanized finish, Anvil Figure 282, MSS SP-69 Type, or approved equal.
2. Piping 10 inches through 24 inches. Ceiling anchor bolts.

L. Except as detailed otherwise on the drawings or elsewhere in this specification, all supports shall be as described below:

1. Suspended Un-insulated and insulated steel and cast-iron soil pipe for water, chilled water, and all other services with stationary piping.

   a. 18 inches and smaller: Single rod, galvanized finish, adjustable clevis hangar, Anvil Figure 260, MSS SP-69 Type 1, or approved equal.
   b. 20 inches through 24 inches: Two rod, galvanized finish, universal trapeze assembly, ¼ x 6 x 4 minimum tube size, Anvil Figure 46, or approved equal.

2. Pipe supported by structural steel, Un-insulated and insulated steel and cast-iron soil pipe for water, chilled water, and all other services with stationary piping.

   a. 18 inches and smaller: U-bolt Cradle support with guides, galvanized finish, with PTFE slide plates, PTP Figure 800, or approved equal.
   b. 20 inches through 24 inches: Heavy duty pipe saddles, galvanized finish, with PTFE slide plates, PTP Figure 2000, or approved equal.

M. Covering on insulated piping shall be protected from damage by the use of protection saddles or protection shields, properly constructed and secured to the covered pipe at points of roller, hanger, and support contact. Provide protection saddles and protection shields as follows.

1. Protection saddles shall be used on all locations where pipe rolls are specified. Protection saddles shall be plain finish Anvil Figure 160, 161, 162, 163, 164, 165, 165A, or 166A depending on pipe size, insulation thickness and supported load, MSS-SP-69 Type 39A and 39B, or approved equal.
2. Protection shields shall be used on all insulated piping not supported by pipe rolls at each hanger, trapeze, or other support. Protection shields shall be galvanized finish, Anvil Figure 167, MSS-SP-69 Type 40, or approved equal.
3. Saddles shall have sufficient depth for the insulation thickness required and shall be notched so that the saddle contact with the pipe is approximately 50 percent of total axial cross section. Protection saddles shall be Anvil Figure 160 series or approved equal. Dimensionally, the saddles shall be in accordance with the following:

Protection Saddles				
Nominal Pipe Size	Saddle Length	Metal Thickness	Arc Span	Center Rib
3/4” – 5”	12”	1/8”	60o	Without Rib
6” – 10”	12”	3/16”	60o	Without Rib
12” – 20”	12”	3/16”	60o	With Rib

4. The scheduled length of saddle is a minimum, as actual length of saddle shall be coordinated with the expansion of pipe at each hanger to assure saddle bears on hanger.

N. Engage a qualified professional engineer to perform pipe stress analysis of final shop drawing piping and design piping guide and anchor locations. Design to comply with wind performance requirements indicated on structural drawings. Pipe anchors shall be located and fabricated or pre-engineered as shown on the design, unless specified otherwise herein.

O. Light-duty and/or pre-engineered spring hangers shall be furnished and installed with the pre-loading as shown on the design drawings. Shop drawings detailing construction and indicating the amount of preloading (in the cold position) shall be submitted for approval prior to installation.

P. Where shown on the design drawings, U-bolts for supporting steel pipe shall be galvanized finish Anvil Figure 137, MSS-SP-69 Type 24, or approved equal.

Q. Where shown on the design drawings, U-bolts for supporting copper tubing shall be plastic coated Anvil Figure 137C, MSS-SP-69 Type 24, or approved equal.

R. All fabricated trapezes, supports, and components shall be galvanized finish, fabricated and installed as shown on the design drawings.

S. For galvanic action protection, use only copper-plated and/or plastic-coated hangers and supports for un-insulated copper tubing. Clips for small tubing may be secured with bolted steel lips which are copper plated if required above.

T. All hanger rods shall be Anvil Figure 146 continuously threaded rods, Anvil Figure 140 smooth rods threaded on both ends, Anvil Figure 278 welded eye rods, Anvil Figure 148 rods with eye ends, or approved equal.

U. All hanger rods for sanitary tubing piping systems shall be encased in PVC pipe or shrink wrap material or shall be smooth rods with threaded ends.

PART 3 - EXECUTION

3.1 GENERAL

A. All piping is shown diagrammatically. The Contractor shall be responsible for field verifying all routing and shall modify as necessary to avoid any conflicts prior to fabrication or installation.

B. The Contractor shall be totally familiar with the existing conditions. The Contractor shall be responsible for rerouting where necessary any interferences with the installation of piping.

3.2 WELDING QUALIFICATIONS

A. Contractor shall also comply with all rules and regulations of the state in which the Work is being performed.

B. All welders shall have been certified by the Contractor. Welders shall be tested on site or in an approved facility with access provided to the Owner to verify welder qualification. Each welder shall be tested and qualified specifically for the work. Prior qualifications shall not be substituted for actual testing of personnel unless the both of the following conditions are satisfied:

1. The welder has worked on the job site within the last 30 days, and
2. The site during this time was under supervision of the Contractor.

C. The identification symbol is to be used to identify the work performed by the welder or welding operator; and after completing a welding joint, he shall identify his work by applying his assigned symbol for permanent record in a manner specified by his employer.

D. Qualifications of the welding procedures to be used on equipment or systems covered by codes or insurance regulations and of the performance of welders and welding operations are required and shall comply with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code and requirements of the Owner's insurance company.

E. Each employer or Contractor shall be responsible for the welding done by personnel of his organization and shall maintain a certified record available to the Designer, Owner or Owner's insurance representative of the procedures used and the welders or welding operators employed by him. This record shall show the date and results of procedures and performance qualifications, and the identification symbol assigned to each performance qualification. The certificate shall be presented to the Designer or to the person authorized by the Designer before the welder(s) start work on the project. The identification symbol is to be used to identify the work performed by the welder or welding operator; and after completing a welding joint, he shall identify his work by applying his assigned symbol for permanent record in a manner specified by his employer. Miscellaneous welding and/or systems not covered by such codes or insurance regulations shall be performed by welders properly experienced but not necessarily certified.

3.3 PIPING

A. The Contractor shall run piping and make final connections to all fixtures and equipment provided under this and other sections of the specifications, and/or shown on the Drawings.

B. Contractor shall install all piping, valves, and devices being furnished by equipment Suppliers in accordance with the Supplier’s requirements and as specified herein. It is the Contractor’s responsibility to review information provided by the equipment Suppliers and provide all Work required by the installation.

C. All the piping shall run as shown on the drawings or as structural and architectural conditions will permit. Piping shall be installed so as not to interfere with the opening of doors or other moving parts nor be near or over any portion of the electrical equipment where there might be any possibility of damage. All valves, strainers, flanges, etc., shall be away from walls, columns, structural steel, and equipment to permit easy access for maintenance and/or replacement.

D. Run piping in straight lines parallel or perpendicular to column lines; riser lines to be plumb with such offsets only as indicated or necessary. No sagging of lines permitted.

E. All pipe, fittings and flanges for butt welding shall be furnished with machine-beveled ends in accordance with ANSI B16.25. Oxygen or machine-cut bevels made at the job site will be accepted only if the cut is smooth and true and all slag is cleaned from the flame-cut surface. If any piping component end is bored or undercut, such boring or undercutting shall not result in the finished wall thickness, after welding, less than the minimum design thickness.

F. After cutting, all pipe shall be reamed to full bore. Remove foreign matter from inside of pipe before installing. Keep installed piping free from dirt and scale and protect open ends from foreign matter. Open ends of piping and equipment shall be properly capped or plugged during installation to prevent dirt or foreign matter from entering the system.

G. Pipe shall be cut accurately to measurements established by the Contractor at the job site and shall fit without springing or forcing. Piping spools or prefabricated assemblies shall be within a tolerance of +/- 1/8-inch overall in all planes.

H. All piping shall be installed in such a manner as to prevent undue stress and strain to piping and hangers. Connecting flanges at equipment shall not be made up until it is determined that no stresses will be placed upon the equipment nozzles due to piping misalignment.

I. Install piping to prevent stresses and strains to piping and hangers from thermal expansion or contraction. Provision for proper loops, offsets, or expansion joints to be responsibility of Contractor. Make provision for servicing and removal of equipment without dismantling piping.

J. All drain piping shall be installed to drain to sumps or the sewer system unless shown otherwise on the design drawings.

K. Uniformly grade gravity drainage lines to elevations shown. If no elevations are given, pitch lines not less than 1/8" per foot.

L. The Contractor shall not use 1-1/4-inch, 2-1/2-inch, 3-1/2-inch or 5-inch pipe sizes except for connections to equipment or devices unless shown otherwise on the design drawings.

M. All piping 2-1/2 inches and larger shall be fabricated by butt welding except where specifically noted to be flanged or threaded. All piping two inches and smaller shall be fabricated by socket-welded or threaded connections as specified in the attached schedules.

N. Remake or replace defective, leaking, or otherwise unsatisfactory joints or material. Peening, caulking, or doping of piping is not permitted.

O. All piping 3 inches diameter or greater and having a design temperature exceeding 200 degF that the contractor desires to install in a different routing than as shown on the drawings must have the rerouting approved by the Engineer in writing before installation.

P. All changes in direction and intersections of lines shall be made with fittings, in conformance with ASME B31.9. Mitering of pipe to form elbows, form tees, or any other similar construction shall not be permitted.

Q. Where branch lines are two or more sizes smaller than the header, weldolet or threadolet type connections may be used. Vent lines may be stubbed in.

R. Unions shall be installed where required on pipe sizes 2" and smaller.

S. Pipe threads shall be made using a single thickness of Teflon pipe thread tape.

3.4 FITTINGS

A. All changes in direction and intersections of lines shall be made with fittings, in conformance with ASME B31.9. Mitering of pipe to form elbows, form tees, or any other similar construction shall not be permitted.

B. Branch connections from mains or headers shall be welded tees except where branch lines are two or more sizes smaller than the header, weldolet or thredolet type connections may be used. Stub-in welded piping is not allowed.

C. Piping to have sufficient number of flanges or unions for convenient installation and removal of piping and equipment. Provide unions or flange connections within four feet of all equipment, so placed to facilitate removal or service of connected equipment. Unions shall be installed where necessary on pipe sizes 2" and smaller and on either side of all threaded valves.

D. Reducing fittings shall be used for all changes in pipe sizes, unless specifically stated elsewhere.

E. All reducers in horizontal hydronic piping shall be eccentric reducing fittings having eccentricity down; hold top level.

3.5 VALVES

A. Locate all shutoff and control valves for easy maintenance access and operation. Where valves must necessarily be located in enclosed spaces, they shall be provided with access panels of sufficient size for operation. Furnish these access panels to proper trades for installation.

B. Valves shall be located on water lines at entering and leaving sides of all equipment per the design drawings to isolate and service the equipment.

C. Locate valves elsewhere as shown on the design drawings.

D. Provide chainwheel operators for manually operated valves 6” and larger, located more than 8 ft above floor or platform below as required in accordance with Owner’s requirements. Operators shall be cast iron or ductile iron adjustable sprocket rims and chain guides with galvanized or brass chain and chain closure links forming a continuous loop of chain at each operator.

E. All valves must be labeled with contractor provided and installed permanent tags. Tags shall be stainless steel with 3/8” high stamped text. Tags shall be securely attached with stainless steel wire.

3.6 VALVE ACCESS

A. Locate all shutoff and control valves for easy access and operation or provide chain operators. Where valves must necessarily be located in enclosed spaces, they shall be provided with access panels of sufficient size for operation. Furnish these access panels to proper trades for installation.

3.7 JOINTS

A. All pipe threads shall be in accordance with ANSI B2.1, right-hand, pipe standard, clean cut, full depth, and tapered. Joints to be made tight without caulking. Approved pipe joint lubricant applied in thin layer, or a single thickness of Teflon pipe thread tape shall be applied to the male thread only. Joints shall be tightened with wrenches that are suitable for the purpose and in a manner that will not cause the protective covering to be injured. No cement of any type is to be used in making joints.

B. Socket-welded connections shall be joined without creating stress by preventing the pipe from touching the bottom in the fitting.

C. Joints in copper pipe shall be made by means of 95-5 solder and sweat joints.

3.8 AIR VENTING

A. Provide 3/4" manual air vents at high points of vertical risers.

3.9 WATER DRAINING

A. Provide 3/4" ball valves at low points and bottom of each riser.

3.10 TEST CONNECTIONS

A. Provide all couplings, plugs, valves, etc. at the appropriate locations to accomplish the required testing of piping systems.

3.11 CONTROL AND INSTRUMENTATION TAPS

A. Install primary control instrumentation taps on piping as required for the devices shown on the P&ID's, piping flow diagrams and on the drawings. Primary connections consist of a 3/4-inch weldolet or threadolet. Components and fabrication shall be governed by the applicable piping schedules which are a part of this section of the specifications.

3.12 FIRE-RATED PARTITIONS

A. Provide permanent firestop system at all piping penetrations of fire-rated walls and floors. Review details on drawing as well as this specification for permissible firestop systems.

B. The firestop system shall have been tested and approved in accordance with ASTM E119 and U.L. 1479 (ASTM E814) and classified for up to 2 hours fire rating.

C. Firestop system shall be type detailed on drawings or intumescent type capable of expanding up to 8 times its original volume.

D. Firestop system to be 3M, Hilti, Nelson, Johns Manville, or Specified Technologies.

E. Firestop system shall be installed in strict accordance with published U.L. approved installation instructions.

F. Piping to pass through the fire-rated partition insulated or non-insulated as specified and detailed.

G. Submit U.L. approved installation drawing for each type of penetration prior to construction.

3.13 NON-RATED PARTITIONS

A. Piping to pass through accumulation walls insulated or non-insulated as specified. Wall should be finished to fit neatly around the piping. Firestopping is not required at non-rated partitions.

3.14 PIPE SLEEVES

A. Pipe sleeves to be Schedule 40 or 18 gage steel. Pipe sleeves shall extend 1-1/2" in excess of partition depth of each side.

B. Pipe sleeves shall be provided at non-rated partitions and floor penetrations. Pipe sleeves to be Schedule 40 or 18 gage steel. Sleeves to extend 1-1/2" in excess of partition depth on each side. Sleeves penetrating floors in wet areas, including all mechanical rooms, shall extend a minimum of 1 inch above the floor. Fill annular space of sleeve with waterproof sealant. Piping requiring sleeves:

1. Chilled Water (CHWS AND CHWR)
2. Potable Water (PW)
3. Continuous Blowdown (CB)
4. Intermittent Blowdown (IB).
5. Chilled water
6. Copper pipes thru masonry walls

C. Provide chromium-plated escutcheon plates for exposed uninsulated pipes projecting through floors or walls in finished spaces. Mechanical rooms and janitor closets are not considered "finished" spaces.

3.15 VENTS AND DRAINS

A. Provide manual air vents at high points of vertical risers and at each water coil.

B. Provide 3/4" hose end gate valves at low points and bottom of each riser.

3.16 TEST CONNECTIONS

A. Provide all couplings, plugs, valves, etc. at the appropriate locations to accomplish the required testing of piping systems.

3.17 HANGERS AND SUPPORTS

A. Hang piping so equipment, flanges, and connections do not bear weight of piping.

B. Adequately support vertical lines at their bases or by a suitable hanger placed in horizontal line near riser or by a base fitting set on pedestal.

C. Pipes not to be hung or supported by pumps. No torque to be applied to pumps by connecting pipes. After final pipe adjustments and initial operation of the pumps, the Contractor shall recheck alignment of pumps and realign as required.

D. Piping shall be supported and braced to prevent movement during system operation, other than required for thermal expansion.

E. Support all piping as shown on the design drawings, if not shown, then from the building structure by means of supports approved in writing by the Designer.

F. Hangers on insulated pipe must be of sufficient size to permit the insulation to pass continuously through the hangers. Support all insulated piping outside the finished covering. Protect insulated piping from damage by use of shields, properly constructed and secured to the covered pipe at points where roller, hanger and support make contact.

G. Where piping is to be hung from the building structural steel, hangers shall be attached by means of C-clamps or beam clamps, for the specific loads, as manufactured by Anvil, Fee & Mason, or approved equal. Welding of hanger rods to building steel will not be permitted, nor drilling or burning holes in building steel, unless specifically detailed on the drawings.

H. All supports and parts shall conform to the latest requirements of ASME Code except as otherwise shown to the contrary on the drawings or modified by requirements of this paragraph of the specifications.

I. Hangers and supports shall be adequate at all static and operating conditions. They shall allow for the free movement due to the thermal expansion and contraction of the piping and equipment and shall prevent stress resulting from transferred weight being induced into the connected equipment.

J. All piping shall be carried on adjustable hangers or properly leveled supports. All parts shall be fabricated and assembled so that they will not be disengaged by movement of the supported piping. Screws or equivalent adjustments shall be provided with suitable locking features.

K. Hanger rods shall be subjected to tensile loading only. At locations where lateral or axial movement is anticipated, suitable linkage shall be provided to permit swing. However, where the horizontal pipe movement is greater than ½-inch or where the hanger rod angularity is more than four degrees from the vertical, the hanger rod shall be offset in such a manner that the rod is vertical in the operating position.

L. All hangers on pipe which will be insulated shall be adequately sized for the insulation to pass continuously through the hangers. All insulated piping shall be supported outside the finished covering.

M. Welding to structural steel must be approved by the Designer burning of holes in the building structural steel is forbidden. Avoid making any holes in the structural steel. Where absolutely necessary for holes in structural steel, holes may be drilled only after written permission of size and location has been approved by the Designer.

N. Support all piping by heavy steel, adjustable hangers, or brackets suitably fastened to structural portion of building. Place hangers in accordance with following tables. In addition, supports shall occur within 24 inches of all changes of direction, at all vertical runs, and within 24 inches of each valve 4 inches and larger.

O. Perforated metal, strap iron, or band iron hangers are not permitted. Offsets in hangers are not allowed. Pipe risers to be supported at regular intervals in pipe shafts within the limits of good practice.

P. If hanger spacing is not noted on the drawings, hangers shall be spaced to prevent excessive sag, bending, or shear stress in the piping and to stay within the maximum safe loading as recommended by the manufacturer of hangers, supports, rods, inserts, ceiling plates, anchor bolts, etc. Based on the recommended safe loading for components from the manufacturer, the required hangar spacing may be less, but in no event shall the spacing exceed the following:

STEEL PIPE – STANDARD WEIGHT MAXIMUM HORIZONTAL SPACING BETWEEN SUPPORTS		
NOMINAL SIZE(IN.)	**WATER SERVICE (FT.)**	**VAPOR SERVICE (FT.)**
½ - 1	7	9
1-¼ – 1-½	9	12
2 – 2 ½	10	13
3	12	15
4 - 5	14	17
6	17	21
8	19	24
10 - 12	22	26
14	25	32
16 - 18	27	35
20	30	39
24	32	42

PVC – SCHEDULE 80 MAXIMUM HORIZONTAL SPACING BETWEEN SUPPORTS		
SIZE (IN.)	**WATER SERVICE (FT.)**	**VAPOR SERVICE (FT.)**
¼ - ¾	2	5
1 - 2	3	5
2-½ - 3-½	4	5
4 - 5	4.5	5
6 - 8	5	5

3.18 QUALITY CONTROL

A. All piping shall be examined, and pressure tested in accordance with ASME B31.9, edition unless noted otherwise. All leaks shall be repaired, and the system retested until no leaks appear.

B. The Contractor shall notify the Owner and Designer prior to each test. Tests are not valid unless witnessed by the Designer or his representative.

C. Non-Destructive Examination (NDE)

1. Visual Examination (VT)

a. Visually examine all pipe welds in accordance with ASME B31.9.

b. All persons performing visual examinations and evaluating examinations shall be certified according to the Contractor's welding policies. Visual examinations are to be performed by the Contractor. As an option, the Contractor may obtain the services of an independent testing agency to perform the examinations.
c. Reports shall be generated for each VT examination and shall be kept available for review by the Owner or Engineer. A list of drawings specifying which welds are covered by the report shall be included.
d. All welds not passing VT examination shall be repaired or replaced at no expense to the Owner. Repair shall be performed using the qualified welding procedures applicable to the original weld. If a welder has five failed welds, he/she may be removed from the project, at the discretion of the Owner.

2. Other Examination Requirements

a. Provide examination for all pipe welds as required in accordance with the ASME B31.9 for each piping system.

D. Pressure Testing

1. General

a. All piping excluding tubing, open ended drains and vents shall be pressure tested to ensure leak tightness per the indicated ASME Piping Code.
b. Piping shall be subjected to hydrostatic testing unless alternative pressure test procedure (e.g., pneumatic) is submitted and approved by Owner and Designer.
c. Provide temporary equipment for testing, including pump and gauges. The gauge shall be accurate to within 3 psig and shall be calibrated within six months of the test as recorded on a sticker on the gauge. Test piping system before insulation is installed or piping is painted. The Contractor may choose to insulate prior to testing and cleaning.
d. Contractor may choose to backfill the trench for underground prior to testing and cleaning the piping system, but only if the Contractor acknowledges and assumes all risks associated with backfilling prior to testing. Should the Contractor choose to backfill prior to testing the piping system and the leak test of the carrier pipe or of the conduit fails, the Contractor shall re-excavate and make all required corrections to the piping system and to any disturbed site improvements or utilities at no additional cost to the Owner.
e. Pressure testing shall be performed following the completion of nondestructive examinations, and all other fabrication, assembly, and erection activities required to provide the system or portions thereof subjected to the pressure test with pressure retaining capability. Remove control devices before testing. Ensure that all expansion joints, anchors, and guides are installed and completed.

f. Fill each section with water and pressurize for indicated pressure and time. The Contractor shall provide air vent valves at all high points in the system to purge air pockets while the system is filling and drain valves at all low points to drain system.

g. The Contractor shall consider that testing may be performed against existing valves and equipment having unknown sealing capability. It is the Contractor's responsibility to provide adequate pumping and test medium to accommodate any leakage through the existing equipment and valves.

h. Testing shall be performed with calibrated test gauges (Contractor furnished) in the presence of the Owner or Engineer.

i. The Contractor shall furnish all temporary pipe, fittings, and pumps required to perform the tests.

j. Pipe hangers, snubbers, or restraints shall be blocked, disconnected or pinned, as required, prior to pressure testing or cleaning and shall be restored to operating condition following such test.

k. Equipment and instruments shall be isolated and openings shall be plugged, as required, to accomplish the required testing and cleaning and to prevent over-pressurizing connecting piping or equipment. Relief and safety valves shall be "gagged" or the valves removed and the respective nozzle blanked for testing of the associated equipment.

l. The equipment to which any piping system is attached shall not be subjected to any line tests. The test pressures apply to the piping materials as specified but shall not be assumed to apply to piping specialties, accessories, or equipment, including safety heads, rupture disks, relief valves, expansion joints, instruments, or filters. Items that may be damaged by the test pressure shall either be removed or blanked off.

m. Lines containing check valves shall have the source of test pressure located on the upstream side.

n. The system shall be filled with water; care being taken that air is completely vented from the top of system so that there are no air pockets remaining.

o. The test water for hydrostatic tests shall be clean and of such quality as to minimize corrosion of the materials in the piping system. The temperature of the test medium shall be a minimum of 60°F, unless the Engineer specifies otherwise. The test pressure shall not be applied until the system and the pressurizing medium are approximately at the same temperature.

p. The leak test shall be considered satisfactory if no leakage is discovered on the piping or at any joints and if no sweating due to porosity is discovered on piping or at joints. Lines requiring repairing shall be retested to the pressure originally specified. The piping system, exclusive of possible localized instances at pumps or packing, shall show no evidence of leaking.

q. Repair piping systems sections which fail required piping test, by disassembly and reinstallation, using new materials to extent required to overcome leakage. Do not us chemicals, stop-leak compounds, mastics, or other temporary repair methods.
r. Drain test water from piping systems after testing and repair work has been completed.
s. For underground piping served by a common concrete anchor, do not hydro test more than one line at a time.

2. Test Pressure

a. The hydrostatic test pressure shall be as defined in Paragraph 137.4.5 of the ASME B31.9 Building Services Piping Code which is 1-1/2 times the design pressure of the system. The Design Pressure for the various pipe services are provided in the Piping Tables.
b. The test pressure shall be continuously maintained for a minimum of 10 minutes, up to 24 hours, as required by the Owner's representative. Owner's representative may allow pressure to be reduced to design pressure and held for such time as may be necessary to conduct the examinations for leakage. Examinations for leakage shall be made of all joints and connections. The piping system shall show no visual evidence of weeping or leaking. Other pressure testing procedures and requirements of ASME B31.9 must be strictly followed.

3. Test Blinds

a. If during the field testing of piping it becomes necessary to insert test blinds in any part of this piping, the Contractor shall provide test blinds.
b. Test blinds shall be equipped with a long handle.
c. The Contractor shall submit a written description of test blinds before testing.
d. The Contractor shall remove all test blinds after testing.

4. Records

a. It is the responsibility of the Contractor to keep accurate, updated records of all hydrostatic testing. The Contractor shall submit a final log of all hydrostatic testing for the Owner's records.
b. The Contractor shall maintain a constantly updated list of the following for all hydrostatic tests:

1) Date and time of test.
2) Hydrostatic test pressure.
3) Piping system tested.
4) Extent of piping system tested so that it can be clearly identified up to what point a piping system has been tested.
5) Test results. All failures shall be indicated with the cause explicitly stated and the corrective action taken.

6) Signed witnesses of each test which shall be one employee of the Contractor and by the Owner or Engineer.

3.19 CLEANING

A. General

1. Procedures listed are recommended procedures only. The Contractor may submit proposals that include alternate cleaning procedures. Alternate procedures are subject to review by the Owner or their designee. Regardless of the procedure used, the Contractor is responsible for achieving the required cleanness.
2. Allow the Owner access to the premises to witness all cleaning and testing operations.
3. Furnish cleaning and sanitization materials and supplies.
4. Contractor is responsible for all pumps, compressors, etc., to provide the motive force for cleaning and flushing piping systems. Provide electrical or other fuel requirements for operation of the cleaning equipment.
5. Blank off permanent plant equipment and fabricate spool pieces to provide a pathway around each piece of equipment. Common types of equipment may share the same spool piece. Move spools from piece to piece until the respective supply and return lines are cleaned. Removal of temporary blanks is the responsibility of the Contractor.
6. Identify, provide, and install temporary branches, fittings, vents, drains, etc., required for performance of cleaning.
7. Remove control valves and other in-line devices that may be damaged by the cleaning method employed or bypassed and cleaned separately.
8. Incorporate sections of piping which are removed for temporary connections in the piping circuit being cleaned or cleaned separately.
9. Return the piping system to its original integrity following the cleaning process.
10. Safety Considerations:

    a. Hold a safety and coordination meeting attended by all cleaning personnel to assure the site safety rules are adhered to. These rules typically include posting cleaning schedules prominently and well in advance, confined space entry permit procedures, audible warnings, flashing lights, etc.
    b. Notify the Owner of special safety precautions that must be taken to protect all personnel working in the area of systems being cleaned. Take steps necessary to protect these people from the hazards identified.

11. Environmental Considerations:

    a. Contractor is required to manage the disposal of leftover and used chemicals incorporated in the cleaning procedures performed. Meet federal, state, and local regulations. The procedures must be in a written form approved by the Owner before cleaning is started.

b. Use of chemicals classified by the EPA as nonhazardous is preferred for onsite cleaning. The Owner must approve variance from this in writing.

12. For water insert cone strainers in the piping service connections to attached equipment and leave there until cleaning has been accomplished to the satisfaction of the owner or their designee.
13. Prior to connection of any instrumentation to instrument piping, blow piping clear to remove all moisture, dirt and line scale.

B. Water Flush:

1. For all water services (process water, boiler feedwater, chemical feed, sample lines, condensate, boiler blowdown, etc.) clean all piping sections by blocking flow to all equipment and thoroughly flushing with city water or owner contracted water at high velocity for 30 minutes.
2. Force sufficient clear water through the piping system to achieve 100 percent of normal operating system velocity. If normal operating system velocity is not possible, use a minimum flushing velocity of at least 2.5 feet per second.
3. Continue flushing until the water discharged to the process sewer is visibly clean.

3.20 PIPE IDENTIFICATION

A. Provide positive identification of the contents of all piping systems by means of a permanent lettered legend giving the names of the contents in full or abbreviated form in accordance with the requirements defined in ASME A13.1. Arrows shall be used to indicated the direction of the flow. Visibility, contrast, type, and size of letters shall be as defined in ASME A13.1.

B. Color shall be used to identify the hazards of the piping contents. Color shall be displayed on the piping and used in combination with a legend. Color may be used in continuous, total length coverage or intermittent displays. Colors preceded by the word “Safety” as shown in Attachment A shall meet the requirements of ASME A13.1 and ANSI Z535.1

C. The legend shall consist of stenciling, lettered tape, or other permanently attached signage meeting the size and color requirements of ASME A13.1. The number and location of identification markers shall be based on the particular piping system and the requirements of ASME A13.1.

D. Stripes/bands shall consist of a circumferential 2-inch stripe coat or 2 inch tape band placed adjacent to the legends but no more than 20 feet apart

E. Legends and pipe markings shall be legible and positioned to be easily read as required in ASME A13.1.

3.21 PIPING SCHEDULES

A. Pipe, valves, and fittings shall be as scheduled on the following pages unless otherwise indicated elsewhere in these Specifications.

P0		
SERVICE		CHILLED WATER (CHWS &CHWR)
PRESSURE		150 PSIG
TEMPERATURE		150 °F
SIZES		2" and Smaller (Non Data Hall or Electrical Room Spaces)
PIPE		ASTM A106 Gr B, Seamless, Schedule 40.
PIPE JOINTS		ANSI B2.1, Threaded.
FITTINGS		ANSI B16.3, 300# malleable iron, ASTM A-197.
FLANGES		ANSI B16.5, 150#, Threaded, ASTM A-105, Faced to match equipment.
UNIONS		ANSI B16.39, 300#, Threaded Malleable Iron, with Iron to Brass Seats, ASTM A-197.
BRANCH CONNECTIONS		ANSI B16.3, 300#, Threaded tee, Malleable Iron, ASTM A-197.
VALVES	SHUT OFF	Gate Valve, 150# , Threaded, Bronze, ASTM B-62, Union Bonnet, Inside Screw Rising Stem, Stockham B-120, or approved equal.
		Ball Valve, 600 psi WOG, Threaded, Bronze, ASTM B-584 C84400, 316 SST Ball and Stem, TFE seats, Apollo Series 70-140, or approved equal.
	THROTTLE	Globe Valve, 150#, Threaded, Bronze, ASTM B-62, Union Bonnet, Inside Screw Rising Stem, Stockham B-22T, or approved equal.
	CHECK	Swing Check Valve, 150#, Threaded, Bronze, ASTM B-62, Threaded Cup, Y Pattern, Stockham B-321, or approved equal.
STRAINERS		Y-Strainer, 250# Threaded, ASTM A126-B Body, Stainless Steel Screen, 20 Mesh, Mueller #11M or approved equal.
GASKETS		Compressed Non-Asbestos Gaskets Garlock Style #3200, 1/16" thick, or approved equal.
NUTS AND BOLTS		A307 grade B / A563 Hex. All hardware to be Zinc coated.
NOTES AND REMARKS		All connections to threaded equipment shall be Schedule XS.
SIZES		2½" through 30"
PIPE		ASTM A53 Gr B, Schedule STD ERW
PIPE JOINTS		Butt-Welded.
FITTINGS		ANSI B16.9, ASTM A234 Gr WPB, Butt-Welded (bore to match pipe).
FLANGES		ANSI B16.5 (bore to match pipe), 150# R.F. Welding Neck or Slip-On, Forged Steel, ASTM A105 (2½" through 24"). ANSI B16.47 Series B (bore to match pipe), 150# R.F. Welding Neck, Forged Steel, ASTM A105 (26" through 30").
UNIONS		Flanged.
BRANCH CONNECTIONS		ANSI B16.9, Schedule Std. Tees, ASTM A234 Gr WPB, Butt-Welded. Where branch and header sizes differ by two or more pipe sizes, ASTM A105, 3000#, "weldolets" and “threadolets” may be used. "Weldolets" shall be Schedule Std. bore.
VALVES	SHUT OFF	Ball Valve, 150# Flanged, ASTM A216 Gr WCB Body, 316 SST Ball & Trim, PTFE Seats & Seals, Flow-Tek Fig. F15 or approved equal. (2½" through 12")
		Gate Valve, 150# Flanged, ASTM A216 Gr WCB, Bolted Bonnet, OS&Y, Stainless Steel Trim, Powell Fig. 1503 or approved equal.
		Butterfly Valve, Lugged, 150LB, Ductile Iron Body, 316SS Disc and Trim, FKM Resilient Seat, Keystone Fig. GRL or approved equal. Geared actuators for valves NPS 8 and larger
	THROTTLE	Globe Valve, 150# Flanged, ASTM A216 Gr WCB, Bolted Bonnet, OS&Y, Stainless Steel Trim, Powell Fig. 1531 or approved equal. (2½" through 24")
	CHECK	Wafer Check Valve, 150# Wafer, ASTM A216 Gr WCB Body, 316 SS Plate & Trim, Metal to Metal Seal, Duo-Chek Style G, or approved equal.
		Wafer Check Valve, 150# Wafer, ASTM A216 Gr WCB Body, 316 SS Plate & Trim, Metal to Metal Seal, DFT Model ALC, or approved equal. (2½" through 24")
		Swing Check Valve, 150# Flanged, ASTM A216 Gr WCB Body, Bolted Cap, Stainless Steel Trim, Powell Fig. 1561 or approved equal. (2½" through 24")

STRAINERS	Y-Strainer, 150# Flanged, ASTM A216 Gr WCB Body, Stainless Steel Screen, 1/8" Perforations, Mueller #781 or approved equal. (2½" through 24")
GASKETS	Compressed Non-Asbestos Gaskets equal to Garlock Style #3200, 1/16" thick (2-1/2" through 8"), 1/8" thick (10" through 30") or approved equal.
NUTS AND BOLTS	A307 grade B / A563 Hex. All hardware to be Zinc coated.
NOTES AND REMARKS	All connections to threaded equipment shall be Schedule XS.

END OF SECTION 23 22 01

SECTION 23 2300 - REFRIGERANT PIPING SYSTEM

PART 1 GENERAL

1.1 WORK INCLUDED

A. Refrigeration piping, valves and fittings to connect remote condensers to coolers in building and split system heat pump or air conditioning systems including computer room air conditioning systems.

1.2 SAFETY CODE

A. Comply with the requirements of ANSI B9.1, Code for Refrigerant Systems.

PART 2 PRODUCTS

2.1 MATERIALS

A. Piping: Type "L" ACR hard copper, ASTM B88.

B. Fittings: Wrought copper.

C. Solder: Silver solder, or phos-copper solder having a melting point of 1125 degrees F. or higher.

2.2 EQUIPMENT

A. Service Valves: Henry valves or equal. Provide packed type receiver, purge, and gauge valves with valve stem seal cap ports.
   1. Valves up to 5/8" O.D.: Henry Figure 516 or equal, diaphragm type.
   2. Valves larger than 5/8" O.D.: Henry Figure 203 or equal.

B. Solenoid Valves: Manufactured by Sporlan Co., or equal, suitable for the type of refrigerant used, and of a type permitting manual lifting of stem for emergency operation. Size valves for pressure drop of 3 pounds at design flow.

C. Refrigerant Filter Dehydrator: Sporlan Co. or equal sealed core type of size recommended by manufacturer for maximum design tonnage. For systems 20 nominal tons and larger, provide replaceable core filter driers.

D. Moisture Indicator: Sporlan Co. See-All type SA-125 or equal.

E. Pipe Supports:
   1. Pipes subject to vibration: Isolation type brackets.
   2. Pipes not subject to vibration: Grinnel No. CT-95 or equal.
   3. Riser clamps: Grinnel CT-121 or equal.

F. Escutcheons: Chrome plated escutcheons sized for pipe.

G. Sleeves: Provide sleeves as specified in Section 23 2201

H. Insulation: Insulate piping as specified in Section 23 0710.

PART 3 EXECUTION

3.1 INSTALLATION

A. Make solder joints with carbon dioxide or nitrogen passing through joints being soldered. Ensure a clean, tight system. Pull a clean rag through each piece of tubing after cutting or reaming.

B. Install pipe and hangers in accordance with hanger manufacturers' printed instructions.

C. Provide escutcheons at all visible wall penetrations in finished areas.

3.2 LEAK TESTING

A. Test for leaks by use of carbon dioxide or nitrogen and a liquid soapsuds solution. Correct leaks found.

B. Evacuate system to 20" vacuum and charge with refrigerant until a pressure of 15 psig is reached. Then test for leaks using a Halide leak detector. Correct leaks found.

C. Pressurize system, with carbon dioxide or nitrogen, to 300 psig on the high side, and 200 psig on the low side, and test for leaks. Correct leaks found.

3.3 SYSTEM DEHYDRATION

A. Dehydrate system by "Double Dehydration" method.

B. Use a suitable vacuum pump. Evacuate system to a vacuum of 0.2" Hg absolute and operate pump for eight hours when that pressure is reached.

C. After eight hours, admit dry nitrogen directly to the system, and then evacuate system to a vacuum of 0.2" Hg absolute and operate pump for four hours.

3.4 CHARGING SYSTEM

A. When system dehydration is complete and all leaks are corrected, charge system with refrigerant.

END OF SECTION 23 2300

SECTION 23 25 15 - WATER TREATMENT FOR CLOSED HYDRONIC SYSTEMS

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Provide a complete water treatment system for the closed chilled water systems as specified herein. Systems to be manufactured by Chem Aqua or approved equal. Provide water treatment system start-up and adjustment.

B. Provide one year supply of water treatment chemicals and systems pre-cleaning chemicals.

C. Submit complete water treatment systems for approval.

D. All chilled water piping and related equipment shall be thoroughly flushed out with pre-cleaning chemicals designed to remove deposition such as pipe dope, oils, loose rust, mill scale and other extraneous materials. Recommended dosages of pre-cleaner chemical products shall be furnished by water treatment supplier and added and circulated throughout the water systems. The water systems shall then be drained, refilled and flushed thoroughly until no foreign matter is observed and total alkalinity of the rinse water is equal to that of the make-up water.

PART 2 - PRODUCTS

2.1 CLOSED CHILLED WATER TREATMENT SYSTEMS

A. Provide water treatment system for chilled water system operating from 70°F to 97°F. Water quality requirements are directed from the ASHRAE liquid cooling manual, table listed below. The only column that applies to this section is FWS.

Table 1 Water Quality Guidelines for the FWS and TCS

Parameter	FWS (Table 5.3, ASHRAE 2014)	TCS (Table 6.2, ASHRAE 2014)
pH	7 to 9	8.0 to 9.5
Corrosion inhibitor(s)	Required	Required
Biocide	—	Required
Sulfide	<10 ppm	<1 ppm
Sulfate	<100 ppm	<10 ppm
Chloride	<50 ppm	<5 ppm
Bacteria	<1000 CFUs/mL	<100 CFUs/mL
Total hardness (as $CaCO_3$)	<200 ppm	<20 ppm
Conductivity	—	0.2 to 20 micromho/cm
Total suspended solids	—	<3 ppm
Residue after evaporation	<500 ppm	<50 ppm
Turbidity	<20 NTU (Nephelometric)	<20 NTU (Nephelometric)

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install and place complete water treatment systems in proper operating condition in accordance with drawings, specifications, and manufacturer's published installation instructions. Provide communication link between water treatment microprocessor and Building Automation System PC.

B. Water treatment equipment manufacturers' representative to supervise systems pre-cleaning, water treatment systems installation and start-up, and train owners' representatives a minimum of 8 hours concerning proper feeding and control techniques. Provide two copies of water treatment systems operating and maintenance manuals to Designer.

END OF SECTION 23 25 15

SECTION 23 29 23 - VARIABLE FREQUENCY MOTOR CONTROLLER

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Furnish complete variable frequency motor controllers (VSMC) as specified herein for the fans and pumps designated. All standard and optional features shall be included within the VSMC enclosure unless otherwise specified.

1.2 QUALITY ASSURANCE

A. To ensure quality and minimize infantile failures at the job site, the VSMC shall be burned in at an ambient of 40 degrees Celsius minimum for at least 120 hours. The VSMC shall be operating a dynamometer, and the load and speed shall be cycled during the test. All optional and special features shall be functionally tested at the factory for proper operation.

1.3 WARRANTY

A. The VSMC shall be warranted by the manufacturer for a period of 36 months from date of start-up. The warranty shall include parts, labor, travel costs, and living expenses incurred by the manufacturer to provide factory authorized on-site service.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

A. VSMC to be as manufactured by ABB, Yaskawa, Danfoss, or approved equal.

B. The VSMC shall convert 3-phase, 60-Hz utility power to adjustable voltage and frequency, 3-phase, AC power for stepless motor speed control from 5% to 100% of the motor's Hz speed. Input voltage shall be as indicated on the equipment schedules on drawings.

C. Convertor Section: Full wave diode bridge rectifier.

D. Invertor Section: Transistorized sine coded pulse width modulated (PWM) type for stepless motor speed control.

E. Silicon-controlled rectifiers (SCRS) or GTOs shall not be used in the circuitry.

F. The VSMC maximum output current rating shall be 110 percent of the motor nameplate full load current.

G. The VSMC and options shall be tested to ANSI/UL Standard 508. The complete drive including all options shall be listed by a nationally recognized testing agency such as U.L. or ETL.

H. The VSMC and options shall comply with the applicable requirements of the latest standards of ANSI, IEEE, and the National Electrical Code. The VSMCs full load amp rating shall meet or exceed NEC Table 430-150.

I. Power line noise shall be limited to a voltage distortion of 3 percent and line notch depth of 10 percent or 16,400-volt microseconds whichever is less as defined in IEEE Standard 519, Guide for Harmonic Control and Reactive Compensation of Static Power Converters. Provide line reactors sized to limit line notching to 10 percent or 16,400-volt microseconds whichever is less.

J. The VSMC shall not emit either conducted or radiated RFI in excess of the limitations set forth in the FCC Rules and Regulations, Part 15, Subpart J, for class A computing devices. The VFD shall have an FCC compliance label. Provide RFI filters if required.

K. The increase in audible motor noise with the VSMC operating shall not exceed 3 decibels.

2.2 BASIC FEATURES

A. The VSMC shall include the following basic features:

1. The VSMC shall be housed in a NEMA 1 wall-mounted enclosure for indoor applications and NEMA 3R rack mounted for outdoor use.
2. The following operator controls shall be located on the front of the enclosure:

    a. Hand/Off/Auto selector switch to start and stop the motor. In the auto position, the drive will start/stop from a remote contact closure.
    b. Auto/Manual selector switch. In the auto position, motor speed is determined by the follower signal. In the manual position, motor speed is determined by the manual speed potentiometer.
    c. Manual speed potentiometer.
    d. Power on pilot light to indicate that the AFC is being supplied by the power line.
    e. Fault pilot light to indicate that the AFC has tripped on a fault condition.
    f. Digital meter to indicate percent speed and percent load.

3. Two sets of form C, dry contacts to indicate when the VSMC is in the run mode.
4. One set of form C, dry contacts to indicate when the VSMC is in the fault mode.

5. When input power returns to normal following a fault trip for under-voltage, over-voltage, or phase loss, the VSMC shall automatically restart. The VSMC shall not automatically restart following fault trips due to overload or over-current.
6. The VSMC shall include a door interlocked, padlockable, input power disconnect switch.
7. Speed Control: The output frequency may be adjusted in proportion to any one of the following:

    a. 0-10 VDC Analog Signal.
    b. 0-5 VDC Analog Signal.
    c. 4-20 MA DC Analog Signal.
    d. 3-15 psig Pneumatic Signal.

8. Coordinate with controls supplier for exact input signal and type to provide proper input follower (i.e., grounded or floating).
9. Provide open protocol BACnet MS-TP, LONtalk, Johnson N2, etc. interface card to connect to Building Automation System.

2.3 PROTECTIVE FEATURES

A. The VSMC shall include the following protective features:

1. Current limiting semiconductor fuses for the power input.
2. Separate overload relay for each motor controlled.
3. Protection against input power under-voltage, over-voltage, and phase loss.
4. Protection against output current overload and over-current.
5. Protection against over-temperature within the VSMC enclosure.
6. Protection against over-voltage on the DC bus.
7. In the event of a power loss, shutdown without component failure. Upon return of power, automatically return drive to normal operation, if the start is in the "ON" condition, being able to restart into a rotating motor regaining positive speed control without shutdown or component failure.
8. In the event of a phase-to-phase short circuit, shutdown safely without component failure.
9. In the event that an input or output power contactor is opened or closed while the drive is activated, no damage to the VSMC shall result.
10. Any disconnect switches between the VSMC and the motor shall include an auxiliary contact interlocked to the VSMC fault trip circuit. In the event that a disconnect switch is opened while the drive is running, the drive shall shut down.
11. DC bus discharge circuit for protection of service personnel.
12. Insensitive to incoming power phase sequence.

2.4 ADJUSTMENTS

A. The VSMC shall include the following adjustments available via potentiometers inside the enclosure:

1. Maximum speed, adjustable 50-100% base speed.
2. Minimum speed, adjustable 0-50% base speed.
3. Acceleration time, adjustable 2-60 seconds.
4. Deceleration time, adjustable 2-60 seconds with override circuit to prevent nuisance trips if deceleration time is set too short.
5. Current limit, adjustable 0-110%.

2.5 SERVICE CONDITIONS

A. The VSMC shall be designed to operate within the following service conditions:

1. Ambient temperature, 0-40 degrees C.
2. 0-95% relative humidity, non-condensing.
3. Elevation to 3300 feet without derating.
4. AC line voltage variation, -5% to 10% of nominal.

2.6 SPECIAL FEATURES

A. The following special features shall be included in the VSMC enclosure. The unit shall maintain its U.L. or ETL listing.

1. A motor starter shall be included in the bypass circuitry for constant speed motor control when the VSMC is taken out of service. Manual bypass shall provide all the circuitry necessary to transfer the motor from the VSMC to the power line, or from the line to the controller while the motor is at zero speed. The bypass circuitry shall be mounted in a separate section of the VSMC enclosure. Two motor contactors, electrically interlocked, shall be utilized. One contactor is to be between the controller and the motor. The other contactor is to be between the bypass power line and the motor providing across-the-line starting for motors 50 hp and less, and part-winding or “soft start” starting for motors greater that 50 hp. Motor overload protection is to be provided in both the controller mode and the bypass mode. The bypass section door shall include a "drive/line" switch, "on/off-reset" switch, and a "load transferred to line" pilot light.
2. The VSMC shall include a main fused disconnect switch or circuit breaker to provide a means of disconnecting all power to both the bypass circuitry and the controller. The disconnect switch or circuit breaker shall be door interlocked and padlockable. The fuses or circuit breaker shall be sized to provide short circuit protection for the motor when in the bypass mode per the NEC.
3. A second disconnect switch, circuit breaker, or contactors shall be provided to disconnect input power to the controller but not the bypass circuitry. This disconnect will allow troubleshooting and testing of the VSMC, both energized and de-energized while operating in the bypass mode.
4. Plug-in test meter shall provide a quick means for monitoring the different signals within the VSMC for start-up and troubleshooting. Where the meter is capable of operating with different horsepower VSMCs, only one meter needs to be supplied.
5. A critical frequency avoidance circuit shall be provided to avoid operation at speeds which cause excessive vibration in the driven equipment.

PART 3 - EXECUTION

3.1 INSTALLATION

A. The manufacturer of the VSMC equipment shall provide a competent, factory trained service technician to supervise the installation, start-up and testing of the VSMC.

B. Install VSMCs in locations shown on the drawings in strict accordance with the manufacturer's published installation instructions.

C. Contractor shall provide such materials and assistance as required by the manufacturer's representative.

D. Division 26 shall provide necessary electrical connections.

E. Contractor shall provide coordination of the necessary controls not provided by the VSMC manufacturer.

3.2 START-UP, TESTING, DEMONSTRATION

A. The manufacturer's factory-trained service technician, assisted by contractor, shall verify correct installation, start-up equipment, and test it as a unit and a part of the system it serves. Verify by adjustments, tests, etc., that the equipment is functioning as specified. Provide three copies of test data to the Owner. As a minimum, check the following items:

1. Motor voltage and frequency.
2. Control input and automatic start/stop.
3. Calibration and adjustment for minimum and maximum speed setpoints and acceleration and deceleration rates.
4. Wire terminations.

B. VSMC manufacturer shall provide a minimum of 4 hours instruction to Owner to demonstrate the operation of the system. Provide three copies of operation and maintenance manual to Owner at completion of instructions.

END OF SECTION 23 29 23

SECTION 23 31 10 SHEET METAL DUCTWORK - LOW PRESSURE

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Low pressure ductwork refers to systems operating at 2.00" w.g. total static pressure with velocities up to 2000 FPM. It is the intent of this specification to provide an installed duct system which will supply the air quantities indicated by the plans and have the lowest possible friction loss with the least possible leakage loss. Friction loss for each system shall not exceed that which is indicated in the A.C. unit schedule as external static pressure or in the fan schedule as static pressure and shall include the losses of all accessories. Friction losses shall be minimized by reduction in the number of offsets and elbows by pre-planning the duct system installation and coordination with other trades to prevent interferences. Access to all accessories requiring maintenance, service and inspection shall be maintained. Radius elbows are preferred for all turns to minimize friction, noise and vibration; and, especially, for sections having large volume or higher velocities and sections which may have turbulences.

B. The contractor shall provide and/or construct all materials, ductwork, joints, transitions, splitters, dampers, access doors, etc., as set forth in these specifications necessary to install the Low Pressure Sheet Metal Ductwork required by the Mechanical Drawings.

C. Low pressure ductwork shall be constructed to meet the following pressure class:

1. Supply ductwork downstream of terminal units: 1.0" pressure class.
2. Supply and return duct connections to fan coil units or single zone air systems (ESP ≤1.0"): 1.0" pressure class.
3. Supply and return duct connections to fan coil units or single zone air systems (ESP >1.0", ≤2.0"): 2.0" pressure class.
4. Exhaust and return ductwork (Fan ESP ≤2.0"): 2.0" pressure class.

1.2 QUALITY CONTROL AND REGULATORY STANDARDS

A. SMACNA Manual: Sheet Metal Tradesman is to have access on the construction site to the Latest Edition of SMACNA "HVAC Duct Construction Standards", (Metal and Flexible). The Manual is referred to in specifications for required construction methods and details. Contractor shall comply with provisions of the SMACNA Manual and more stringent requirements of this specification.

B. Quality control involves not only the general performance requirements for all air ducts, but also quality workmanship which includes layout preplanning so that offsets, rises, falls, elbows, fittings, etc., are minimized or eliminated. General performance requirements for all ducts include:

1. Dimensional stability (shape deformation and strength).
2. Containment of the air being conveyed (leakage control).
3. Vibration (fatigue and appearance).
4. Noise (generation, transmission or attenuation).
5. Exposure (to damage, weather, temperature extremes, flexure cycles, wind, corrosive atmospheres, biological contamination, flow interruption or reversal, underground or other encasement conditions, combustion, or other in-service conditions).
6. Support (alignment and position retention).
7. Thermal conductivity (heat gain or loss and condensation control).

C. Provide galvanized duct materials which meet applicable requirements of SMACNA manual and local and state codes, whichever is the most stringent.

D. Support ductwork in accordance with applicable requirements of SMACNA manual, local and state codes, and details on plans, whichever is the most stringent.

E. Materials used as sealers, liners, pre-insulated jackets and flexible ducts shall comply with a flame spread rating of 25 or less and a smoke developed rating of not over 50.

F. Joint sealer shall meet the requirements of UL181A or UL181B as applicable.

G. Duct sealant classification: Seal all transverse joints, longitudinal joints and duct wall penetrations in accordance with SMACNA Class A.

1.3 SUBMITTALS AND SHOP DRAWINGS

A. Submit material/product data to designer for approval ONLY when it deviates from products specified in Part 2 herein.

PART 2 - PRODUCTS

2.1 MATERIAL

A. Sheet Metal, Angles, Bar Slips, Hangers, and Straps: Galvanized steel.

B. Screws: Cadmium plated.

C. Joint Sealer: Manufactured by Hardcast, Inc., Two-Stage Sealant Process.

1. Stage 1: Apply fiber DT tape.
2. Stage 2: Brush on RTA-50 sealant over fiber tape.

2.2 FABRICATION

A. Provide a rectangular or round duct where required on drawings of prime quality galvanized steel sheets, thickness and reinforcement as required by the following schedule, SMACNA, or local and state codes, whichever is more stringent. When fabricating low pressure ductwork, largest duct dimension governs the entire duct and complete joint.

DUCTWORK GAUGE AND REINFORCEMENT SCHEDULE				
MAXIMUM DUCT DIMENSION (IN.)	DUCT GAUGE	SLIP GAUGE	STANDINGS	REINFORCEMENT
Up thru 18	24	24	- -	- -
19 - 30	24	24	1 x 24 ga.	No
31 - 42	22	22	1 x 24 ga.	No
43 - 54	22	22	1-1/2 x 20 ga.	1-3/8 x 1/8 Band Iron
55 - 60	20	20	1-1/2 x 20 ga.	1-3/8 x 1/8 Band Iron
61 - 84	20	20	1-1/2 x 18 ga.	1-1/2 x 1-1/2 x 1/8 Angle
85 - 96	18	20	1-1/2 x 18 ga.	1-1/2 x 1-1/2 x 3/16 Angle
Over 96	18	20	2 x 18 ga.	2 x 2 x 1/4 Angle

B. Duct dimensions shown on drawings indicate inside clear dimensions. Make allowances in sheet metal size for duct requiring internal duct liner to provide "inside clear" dimensions.

C. In addition to the requirements above, add supplemental bracing as necessary to prevent sagging, drumming, and vibration.

D. Round prefabricated 24 gauge slip joint duct may be used on exhaust and return duct 12" and smaller and for runout duct to boxes, diffusers, registers, and grilles.

1. Secure duct sections and fittings with sheet metal screws.
2. Make connections of round duct to rectangular duct using "spin-in" collars with manual volume damper.
3. Transverse and longitudinal slip joints shall be sealed with approved sealer.

E. Provide transverse joints of "s" and drive construction at least every eight feet on duct whose larger side is less than 18". Seal all transverse joints with joint sealant material.

F. Provide transverse joints, or equivalent supplemental angle reinforcing on 4 foot centers on duct whose larger side is greater than 18". At the contractor's option, duct mate or equal joint system may be substituted for "s" and drive construction. Seal all transverse joints with joint sealant material.

G. Longitudinal seams shall be Pittsburg Lock or grooved seams closed tightly and evenly. Button punch snap lock longitudinal seam construction shall not be allowed. Seal longitudinal joints which prove to leak with joint sealant material.

H. Cross break ductwork over 10" dimension, either side.

I. Do not exceed 20 degree angle of slope for increase-in-area transitions.

J. Do not exceed 20 degree angle of slope for decrease-in-area transitions.

K. Do not exceed 30 degrees on the entering side or 45 degrees on the leaving side for angle of transitions at connections to equipment without the use of approved vanes. 20 degree angle is preferred and should be used space permitting.

L. Provide Ells fabricated to one of the following specifications in order of preference (SMACNA Figures 4-2 through 4-4 and Figure 4-9 and Chart 4-1):

1. Unvaned elbow with the throat radius equal to 3/4 of the width of the duct and with a full heel radius.
2. Six inch throat radius with full radius, single thickness vanes and full heel radius. Maximum unsupported length of vanes shall be 36". Vanes shall be securely fastened to runners. All vanes shall be secure and stable in installed operating position. Construct vane edges to project tangents parallel to duct sides.
3. Square elbows with single thickness turning vanes. Maximum unsupported length of vanes shall be 36". Vanes shall be securely fastened to runners. All vanes shall be secure and stable in installed operating position. Construct vane edges to project tangents parallel to duct sides.
4. Radius elbows are the preferred fitting. Square elbows are to be used only when available space prevents the use of radius elbows.

M. Provide offsets as necessary in accordance with SMACNA Figure 4-7.

N. Make branch connections and tees in one of the following manners:

1. Converging radius elbow with MVD. (SMACNA Figure 4-5).
2. 45-degree entry with MVD. (SMACNA Figure 4-6).
3. Round spin-in fitting with MVD.

O. Space duct joints to avoid cutting them for branch take offs and outlet collars.

PART 3 - EXECUTION

3.1 INSTALLATION, APPLICATION, ERECTION

A. Support ductwork on each side of the duct with suitable sheared strips of galvanized metal or 1" x 1/8" galvanized steel band iron hangers.

B. Attach hangers to the ductwork using sheet metal screws.

C. Secure hangers to concrete structure with approved anchor shields and to steel structure by means of C-clamps.

D. Space hangers approximately eight feet along the duct except as noted below.

E. For ducts 60" and larger and heavy sections, such as welded duct and sound absorbers, space hangers at approximately four foot intervals.

F. Obstructions shall not be located within ducts.

G. Do not exceed 45 degrees for easement transition angle.

H. Seal all transverse joints with approved sealer in accordance with manufacturers' directions. Also, seal longitudinal joints which prove to leak.

I. Insulation: Where drawings and insulating specifications indicate that ducts are to be insulated make provisions for neat insulation finish around damper operating quadrants, splitter adjusting clamps, access doors, and similar operating devices. Metal collar equivalent in depth to insulation thickness and of suitable size to which insulation may be finished to be mounted on duct.

J. Counterflashing: Counterflash all ducts where they pierce the roof.

K. Pitot Ports: Pitot ports for measuring airflow to be located in each main duct at the downstream end of the straightest run of the main and before the first branch take-off. Pitot ports to be formed by drilling 7/16" holes in the duct, lined up perpendicular to airflow on maximum 8" centers and at least three to a duct, evenly spaced. Holes to be plugged with plastic plugs. Provide access to these for future rebalancing.

3.2 **CLEANING**

A. Clean ductwork thoroughly to assure all foreign matter, dirt, etc. is removed.

END OF SECTION 23 31 10

SECTION 23 33 10 -SHEET METAL SPECIALTIES

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Specialties to be submitted and approved before starting installation.

B. Items to be installed approximately as shown on drawings taking into account differences in mechanical equipment submitted and that shown on contract documents. Each item to be installed so that it is readily accessible for maintenance, repair, and/or setting and balancing.

C. Diffusers, registers, and grilles to have ratings certified by Air Diffusion Council and tested per ADC Equipment Test Code 1062R2 and ASHRAE Standard 36B-63.

D. Refer to drawings for diffuser, register, and grille sizes and number of airflow directions.

PART 2 - PRODUCTS

2.1 FIRE DAMPERS

A. Fire dampers to be U.L. listed in accordance with UL-555. Fire dampers to be held in an open position with a 165 degree F fusible link and arranged to lock in position on closure.

B. Fire dampers for rectangular duct to be type "B" (Blades out of air stream) and for round duct to be Type "C" (Blades and frame out of air stream). Fire dampers located behind sidewall registers and grilles and others specifically indicated on drawings to be Type "A" (Frame and Blades in air stream). Fire dampers to be multi-leaf type with spring closing for horizontal mounting and weighted-gravity closing for vertical mounting. Dampers to be steel construction with rust resistant finish and provided with a factory-installed mounting sleeve suitable for structure. Mount per manufacturer's published U.L. approved installation instructions. Manufacturer models which provide square to round or round oval transitions are acceptable.

C. See Architectural drawings for hour-rating of walls and/or floors. Dampers to be compatible with hour ratings.

D. Fire dampers to be Ruskin Model IBD2 Curtain Type Static Fire Dampers

2.2 DAMPERS

A. Manual Volume Dampers (MVD): Manual volume dampers to be hand-operated type dampers constructed of galvanized steel, minimum 22-gauge for duct widths 18" and less, minimum 16-gauge for duct widths greater than 18". Dampers for ducts to 12" height and 12" diameter to be single blade carried on a 3/8" round steel rod mounted inside of duct without frame and fitted with locking type quadrant and brass end bearing plate accurately drilled and secured to duct. Dampers for ducts greater than 12" height to be multi-blade type, 12" maximum blade width up to 30" blade length and 10" maximum blade width over 30" blade length. Blades to be mounted on frame with brass sleeve bearings interconnected for operation from one locking type hand quadrant. Round pivot rods to have section faced flat to receive locking setscrew in locking quadrant. Refer to SMACNA manual Figures 2-14 and 2-15.

1. For manual damper locations above a rigid or non-accessible ceiling or where damper access is limited, a remote damper operator shall be used. Damper operator to be self-locking worm gear designed for 3/8” damper shaft. Shaft extension to be 3/8” square rod with coupler. Remote operator to be provided with wrench operated shaft adjustment, position indication and lock nut. Where straight shaft extension cannot be used due to accessibility, a flexible cable operator with compatible damper operator and regulator may be utilized. Damper operator, shaft and regulator shall be designed for minimum 35 in-lb torque.

B. Backdraft Dampers (BDD): Backdraft dampers to be Ruskin Model **CBD6** or approved equal low-leak counterbalanced backdraft dampers. Dampers to be heavy-duty type suitable for air velocities to 2500 fpm with all extruded aluminum construction, minimum 0.81" thick frame, and minimum .050" thick blades on maximum 4" centers. Provide blades with vinyl edge seals. Provide dampers with aluminum linkage and corrosion resistant type bearings. Provide dampers with adjustable counterbalances on blades to assist closing.

2.3 SQUARE CEILING DIFFUSERS

A. Provide Titus Omni or approved equal round neck, square panel face ceiling diffusers at all locations designated by schedule on drawings. Diffusers to be steel or aluminum construction. Frame to be flush mount for diffusers in "hard" ceilings and lay-in T-bar mount for diffusers in lay-in ceilings. Finish to be baked-on, off-white enamel.

2.4 SIDEWALL SUPPLY REGISTERS

A. Provide models designated by schedule on drawings. Registers to be all aluminum construction complete with removable and rotating fixed horizontal blade core, and attached rear set of individually adjustable vertical blades. Finish to be baked-on, off-white enamel. Border to be curved, Titus.

2.5 DRUM LOUVERS

A. Provide models designated by schedule on drawings. Drum louvers to be all aluminum construction. Drum louver shall be adjustable to direct the airstream at any angle up to 30 degrees from the louver centerline by rotating the drum or by adjusting the position of the pivoted vanes.

2.6 SIDEWALL RETURN REGISTERS

A. Provide models designated by schedule on drawings. Registers to be all aluminum construction complete with removable and rotating fixed horizontal blade core. Finish to be baked-on, off-white enamel. Border to be curved, Titus Type.

2.7 CEILING RETURN & EXHAUST REGISTERS

A. Provide models designated by schedule on drawings. Registers to be complete with 1/2" cube egg-crate aluminum grid. Finish to be baked-on, off-white enamel. Border to be flush mounted frame style.

2.8 FLEXIBLE CONNECTORS

A. Install UL listed flexible duct connectors between duct and fan/equipment connections. Flexible duct connectors to be made of 28-ounce, heavy glass fabric double coated with neoprene.

2.9 FLEXIBLE DUCT

A. Flexmaster Type 1M Acoustical Attenuating or Approved equal. Submit acoustical performance of any alternate product for prior approval.

1. Characteristics of flexible duct:

    a. Approved as UL-181 Class 1 air duct.
    b. Flame spread rating less than 25 and smoke developed rating less than 50.
    c. Rated for 6" w.g. positive pressure, 4" w.g. negative pressure, and 5000 fpm air velocity.
    d. Tear and puncture resistant reinforced CPE inner liner mechanically locked together with a corrosive resistant galvanized steel helix.
    e. Insulated with minimum 1/2" thick fiberglass insulation with vapor barrier jacket.

B. Seal off the insulation jacket at its ends and at joints with mastic, Hardcast, or similar material. Replace flexible duct if jacket is punctured.

C. Flexible duct is NOT to be used for runouts where it must pass through walls or through smoke or fire partitions. Flexible duct is not to be used in exposed application. Flexible duct lengths shall not exceed 6 feet at each connection.

D. No bends shall be made in flexible duct with the center line radius less than one and one-half duct diameter and only one bend may occur per 6 foot length of duct material.

2.10 DUCT ACCESS DOORS

A. Duct access doors to be provided for access to all coils, fire, fire/smoke, and smoke dampers, automatic and backdraft dampers, duct smoke detectors, static pressure and air volume sensing devices, and other equipment installed in ducts and at other points indicated on drawings.

B. Access door construction and airtightness must be suitable for the duct pressure class used (low, medium, or high).

C. Access doors to be double-panel, galvanized steel construction with minimum 1" rigid insulation between panels. Access doors in exhaust duct and unlined return duct may be uninsulated single panel, galvanized steel construction. Doors to mount in rigid frame constructed of formed galvanized steel. Angle iron bracing to be used as required to provide rigid assembly. Doors to hinge on one side with door latch on opposite side.

D. Access doors in ductwork shall fully comply with Figure 2-12 and 2-13 of SMACNA manual. Casing access doors shall fully comply with Figure 6-11 and 6-12 of SMACNA manual.

E. Doors to close against gasket seal.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Installation to be in accordance with manufacturers' published installation instructions as well as applicable sections of SMACNA manual.

B. Provide all screws, bolts, nuts, and inserts required for attaching sheet metal specialty items to ducts, walls, floors and ceilings.

END OF SECTION 23 33 10

SECTION 23 64 23 - PACKAGED AIR COOLED MAGNETIC BEARING CHILLER

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Packaged air cooled chiller to be owner furnished, contractor installed. Contractor shall install as specified herein and on the drawings. Chiller performance rated according to requirements in AHRI 550/590.

1.2 WARRANTY

A. Unit Warranty: Manufacturer shall include parts and labor warranty on all equipment and material of its manufacture against defects in workmanship and material for a period of twenty-four (24) months from date of substantial completion.

B. Compressor Warranty: Manufacturer shall warrant all compressors against defects in workmanship and material for a period of sixty (60) months from date of shipment

1.3 DELIVERY AND HANDLING

A. Unit shall be delivered to job site fully assembled with all interconnecting refrigerant piping and internal wiring ready for field installation and charged with refrigerant and oil by the Manufacturer.

B. Provide protective covering over vulnerable components for unit protection during shipment. Fit nozzles and open ends with plastic enclosures.

C. Unit shall be stored and handled per Manufacturer’s instructions.

PART 2 - PRODUCTS

2.1 EQUIPMENT REQUIREMENTS

A. Owner’s chiller performance requirements indicated on drawings.

PART 3 - EXECUTION

3.1 REQUIREMENTS OF MANUFACTURER'S REPRESENTATIVE

A. Manufacturer shall furnish the services of a trained representative to supervise installation, testing, and initial operation of chillers.

B. The manufacturer's representative shall instruct the owner's operating personnel in the operation of the chillers for a minimum period of 4 hours. Furnish written confirmation signed by owner verifying satisfactory installation and completeness of instruction.

3.2 INSTALLATION

A. The contractor shall install the chillers in accordance with the manufacturer's published installation instructions as recommended by the manufacturer's representative. Chiller to be installed on top of structural steel platform. Refer to structural drawings and Division 05 for additional requirements.

B. The contractor shall install all interconnecting piping, valves, and fittings as required for a complete operating system.

END OF SECTION 23 64 23

SECTION 23 7520 PACKAGED HEAT RECOVERY AC UNITS [CUSTOM UNITS]

PART 1 GENERAL

1.1 WORK INCLUDED

A. Provide packaged air source heat pump, heat recovery air conditioning units as manufactured by Valent or approved equal.

1.2 QUALITY ASSURANCE

A. Unit cooling capacity shall be in accordance with and tested to AHRI Standard 210/240 or 360.

B. Units up to 20 tons capacity shall carry the AHRI compliance label.

C. Units shall be safety certified in accordance with UL Standard UL465 and ANSI Standard Z21.47.

D. Unit shall be safety certified by an accredited testing laboratory. Unit nameplate shall carry the label of the certification agency.

E. Unit shall be shipped completely assembled by the manufacturer including all standard items and accessory items.

F. Unit shall be 100 percent run tested by the manufacturer with a copy of the run test report shipped with the unit.

PART 2 PRODUCTS

2.1 EQUIPMENT

A. Unit Construction:
1. Unit shall be completely factory assembled, piped, wired and shipped in one piece.
2. Unit shall be specifically designed for outdoor application with a fully weatherproof cabinet.
3. Unit shall be designed for mounting on a **slab-on-grade mounted** curb. Elevated units shall have equipment base rails mounted directly to structural steel.
4. Cabinet shall be constructed entirely of double walled, G90 galvanized steel with the exterior constructed of 18 gauge or heavier material.
5. The unit roof shall be cross broken and/or sloped to assure drainage.

6. Access to compressor(s), controls, filters, fan(s), heating section, and other items needing periodic checking or maintenance shall be through hinged access doors with a quarter turn latch (door fastening screws are not acceptable).
7. Air side service access doors shall be fully gasketed with rain break overhangs. Air side access doors shall have an internal metal liner to protect the door insulation.
8. Unit exterior shall be painted with 2-part polyurethane paint over a wash primer and a paint grip type galvanized steel.
9. The interior side of all exterior panels shall be entirely insulated with 2" thick, one pound density, neoprene coated, fiberglass insulation.
10. Unit shall be provided with interior insulation liners to provide double wall construction. Interior wall shall be coated for corrosion resistance.
11. Insulate base on units not mounted on a curb.
12. All openings through the base pan of the unit shall have upturned flanges of at least 1/2" in height around the opening through the base pan.
13. Unit shall have decals and tags to indicate unit lifting rigging, service areas, and caution areas.
14. Wiring diagrams shall be both "point-to-point" and "ladder" diagrams. Wiring diagrams shall also be laminated in plastic and permanently fixed to the control compartment door.
15. Wiring shall be color coded and marked with identification on each end.

B. Fans:
1. Fan(s) shall be entirely self-contained on a slide deck for service and removal from the cabinet.
2. All motors 1 horsepower and larger shall have belt-driven fans. All motors less than 1 horsepower shall have direct-driven fans. Belt-driven fan(s) shall have backward inclined airfoil blades. Adjustable v-belt drive shall be provided with a minimum rating of 140 percent of the motor nameplate brake horsepower when the adjustable pulley is at the minimum RPM. Direct-driven fan(s) shall have forward curved blades.
3. Fans, drives, and motors shall be dynamically balanced.

C. Condensing Section:
1. The condensing section shall be equipped with direct-drive, vertical discharge condenser fan(s).
2. The condenser coil shall be sloped at least 30 degrees from horizontal to protect the coil from damage. If condenser coil is not sloped for protection, louvered coil guards shall be provided.
3. Condenser coil(s) shall be copper tubes with aluminum fins mechanically bonded to the tubes.
4. Condenser coil(s) to be sized for a minimum of 10 degrees sub-cooling.

D. Evaporator Coil:
1. Evaporator coil(s) shall be copper tubes with aluminum fins mechanically bonded to the tubes.
2. Evaporator coil(s) shall have galvanized steel end casings.
3. Evaporator coil(s) shall have equalizing type vertical tube distributors with a top suction connection.

4. Evaporator coil(s) for multi-compressor units shall be circuited with one circuit and expansion valve per compressor.
5. Unit shall be provided with stainless steel drain pan.

E. Refrigeration System:
1. Heat pump cooling/heating compressor(s) shall be of the hermetic scroll type with internal thermal overload protection.
2. All units over 7-ton capacity shall be multiple stage and shall have a minimum of two stages of capacity control.
3. Compressor(s) shall be mounted in an isolated compartment to permit operation of the unit without affecting airflow when the compressor compartment is open.
4. Compressor(s) shall be isolated from the base pan and supply air to avoid any transmission of noise from the compressor into the building area.
5. System shall be equipped with thermostatic expansion valve type refrigerant flow control.
6. System shall be equipped with automatic reset low pressure and manual reset high pressure refrigerant controls. Provide indoor coil freezestats, and current and temperature sensitive overload devices. Each device to be wired to prevent compressor restart until reset at thermostat.
7. Unit shall be equipped with Schrader type service fittings on both the high side and low pressure sides of the system.
8. Unit shall be equipped with refrigerant liquid line filter driers.
9. Unit shall be fully factory charged with refrigerant R-454B.
10. 5-year compressor warranty shall be provided.
11. Unit shall be provided with 0 degree F low ambient control.
12. Unit shall be provided with hot gas bypass on each refrigerant circuit.
13. All circuits shall be equipped with liquid line sight glass.

F. Dehumidification: Unit shall be provided with factory-mounted minimum 15 degree F hot gas reheat coil piped to the lead refrigerant system and all necessary refrigerant piping, valves, and controls.

G. Heat Recovery:
1. The unit shall have a factory-mounted and tested heat wheel. The heat wheel shall be mounted in a rigid frame containing the wheel drive motor, drive belt, wheel seals and bearings. These components shall form a cassette which shall be removable from the unit without the use of tools.
2. The energy recovery cassette shall contain a total energy recovery heat wheel constructed of a lightweight polymer material with permanently bonded desiccant coating. The energy recovery wheel media shall be capable of removal from the cassette and replacement without the use of tools. Wheel media shall be cleanable using hot water or light detergent without degrading the latent efficiency.
3. The unit shall have an exhaust fan adjustable direct drive. A backdraft damper shall be included with the exhaust fan.
4. The unit shall have filters as scheduled.

H. Outside Air:
1. Outside air shall be **100** percent with an adjustable motor-operated outside air damper constructed of extruded aluminum blades with rubber

edge seals and aluminum end seals. Damper blades shall be gear driven and designed to have no more than 25 cfm of leakage per square foot of damper area when subjected to 2" w.g. air pressure differential across the damper. Damper motor shall be spring return to ensure closing of outside air damper during periods of unit shutdown or power failure.

I. Filters:
   1. Unit filters indicated on drawings.
   2. Provide clogged filter switch.
   3. Provide filter gauge.

J. Electrical:
   1. Unit shall be provided with a factory installed and wired internal non-fused disconnect switch.
   2. Unit shall be provided with a factory installed and factory wired 115-volt, 13-amp ground fault service receptacle.

K. Controls:
   1. Provide terminals for connection to controls provided under separate controls section.
   2. Provide unit mounted make-up air programmable microprocessor controller with On-Off hot gas reheat to control discharge air temperature and humidity conditions based on outside air temperature and humidity conditions. Provide with discharge air temperature sensor and outside air temperature and humidity sensors.
   3. Provide unit mounted heating/cooling/dehumidification programmable microprocessor controller to control space/return air temperature and humidity conditions. Provide with space/return air temperature sensor, space humidity sensor, discharge air temperature sensor and outside air temperature sensor.
   4. Provide one hand-held service tool with keypad and LCD display to communicate with unit programmable controller and allow user to view any temperature or output condition and change any setpoint for any unit. Turn service tool over to Owner at project completion. Start up and verify unit controls and system manager are operating properly.
   5. Provide one system manager with keypad and LCD display to communicate with unit programmable controller and allow user to view any temperature or output condition and change any setpoint for any unit. Locate system manager on wall in space indicated on drawings. Connect system manager to each unit controller with 2-conductor twisted pair with shield (Beldon #82760 or equal) per manufacturers' published installation instructions. Start up and verify unit controls and system manager are operating properly.

L. Curb: Roof curbs shall be constructed of galvanized steel Slab on grade mounted curbs shall be minimum 30" high with side duct connections. Curbs shall be fully gasketed between the curb top and unit bottom. Curbs shall provide full perimeter support, cross structure support and air and water tight seal for the unit.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install unit in accordance with manufacturers' published installation instructions.

B. Manufacturers' representative service technician to provide start-up supervision for each unit.

C. Duct connections to units to allow for straight and smooth airflow. Connections to unit to be made with flexible duct connections.

D. Drain lines to be trapped and run full size from drain pan connection to discharge as indicated on plumbing drawings.

END OF SECTION 23 7520

SECTION 23 7556 - MULTI INDOOR UNIT VARIABLE REFRIGERANT FLOW SYSTEM

PART 1 GENERAL

1.1 SYSTEM DESCRIPTION

A. Simultaneous Heating and Cooling Heat Pump: The VRF (Variable Refrigerant Flow) system shall be a simultaneous cooling and heating heat pump. The simultaneous heating and cooling VRF system shall consist of an outdoor unit, high efficiency heat recovery units designed for minimum piping and maximum design flexibility, indoor units, and controls by the equipment manufacturer. Every indoor unit shall be independently capable of operating in either heating or cooling mode regardless of the mode of other indoor units. The system shall be capable of changing mode of individual indoor units (cooling to heating or heating to cooling) within a maximum time of 5 minutes to ensure indoor temperature can be properly maintained.

1.2 MANUFACTURERS

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

1. Basis of Design: Trane.
2. Alternate manufacturers: Daikin, Mitsubishi, LG, Toshiba-Carrier or Sanyo.

B. All manufacturers other than the basis of design are required to coordinate all manufacturer specific requirements with all associated trades. Any additional costs associated with the alternate equipment including but not limited to electrical wiring costs, piping costs, insulation, ceiling systems coordination and engineering design costs shall be covered by the equipment manufacturer and sub contractor. No additional costs shall be incurred by the owner or designer.

1.3 QUALITY ASSURANCE

A. The units shall be listed by Electrical Laboratories (ETL) and bear the ETL label.

B. All wiring shall be in accordance with the National Electrical Code (N.E.C.).

C. The units shall be manufactured in a facility registered to ISO 9001 and ISO14001 which is a set of standards applying to environmental protection set by the International Standard Organization (ISO).

D. A full charge of R-32 for the condensing unit only shall be provided in the condensing unit.

E. The VRF system shall be installed by a licensed mechanical contractor trained by the VRF equipment manufacturer or certified manufacturer’s agent.

F. Commissioning shall be performed by the manufacturer or certified manufacturer's agent.

1.4 STORAGE AND HANDLING

A. All VRF equipment shall be stored protected from weather, extreme temperature, etc. as suggested by the manufacturer. All VRF equipment shall be moved, lifted, etc. as suggested by the manufacturer.

1.5 WARRANTY

A. VRF equipment shall be warranted by the manufacturer's limited warranty for a period of one year from date of substantial completion. Manufacturers shall provide an extended warranty including 1 additional year parts and 5 additional year's compressor.

PART 2 PRODUCTS

2.1 SIMULTANEOUS HEATING AND COOLING OUTDOOR UNIT

A. General: The outdoor unit shall be used specifically with manufacturer approved piping components and air handling units. The outdoor units shall be equipped with multiple circuit boards that interface to the VRF controls system and shall perform all functions necessary for operation. Each outdoor unit module shall be completely factory assembled, piped and wired and run tested at the factory.

1. All units requiring a factory supplied twinning kits shall be piped together in the field, without the need for equalizing line(s). If an alternate manufacturer is selected, any additional material, cost, and labor to install additional lines shall be incurred by the contractor.
2. Outdoor unit shall have a sound rating no higher than 60 dB(A) individually or 64 dB(A) twinned. Units shall have a sound rating no higher than 50 dB(A) individually or 53 dB(A) twinned while in night mode operation. If an alternate manufacturer is selected, any additional material, cost, and labor to meet published sound levels shall be incurred by the contractor.
3. All refrigerant lines from the outdoor unit to the BC (Branch Circuit) Controller (Single or Main) or heat recovery box shall be insulated.
4. Outdoor unit shall be able to connect to up to 50 indoor units depending upon model.
5. The outdoor unit shall have an accumulator with refrigerant level sensors and controls.
6. The outdoor unit shall have a high pressure safety switch, over-current protection, crankcase heater and DC bus protection.
7. The outdoor unit shall have the ability to operate with a maximum height difference of 164 feet and have total refrigerant tubing length of 1804-2625 feet. The greatest length is not to exceed 541 feet between outdoor unit and the indoor units without the need for line size changes or traps.

8. The outdoor unit shall be capable of operating in heating mode down to -4 degrees Fahrenheit ambient temperature or cooling mode down to 23 degrees Fahrenheit ambient temperature, without additional low ambient controls. If an alternate manufacturer is selected, any additional material, cost, and labor to meet low ambient operating condition and performance shall be incurred by the contractor.
9. The outdoor unit shall be capable of operating in cooling mode down to -10°F with optional manufacturer supplied low ambient kit.
10. Manufacturer supplied low ambient kit shall be provided with predesigned control box rated for outdoor installation and capable of controlling kit operation automatically in all outdoor unit operation modes.
11. Manufacturer supplied low ambient kit shall be listed by Electrical Laboratories (ETL) and bear the ETL label.
12. Manufacturer supplied low ambient kit shall be factory tested in low ambient temperature chamber to ensure operation. Factory performance testing data shall be available when requested.
13. The outdoor unit shall not cease operation in any mode based solely on outdoor ambient temperature.
14. The outdoor unit shall have a high efficiency oil separator plus additional logic controls to ensure adequate oil volume in the compressor is maintained.
15. Unit must defrost all circuits simultaneously in order to resume full heating more quickly. Partial defrost which may extend “no or reduced heating” periods shall not be allowed.
16. Unit Cabinet: The casing(s) shall be fabricated of galvanized steel, bonderized and finished. Unit cabinets shall be able to withstand 960 hours per ASTM B117 criteria for seacoast protected models.

B. Fan:

1. Each outdoor unit module shall be furnished with one direct drive, variable speed propeller type fan. The fan shall be factory set for operation under 0 in. WG external static pressure, but capable of normal operation under a maximum of 0.24 in. WG external static pressure via dipswitch.
2. All fan motors shall have inherent protection, have permanently lubricated bearings, and be completely variable speed.
3. All fan motors shall be mounted for quiet operation.
4. All fans shall be provided with a raised guard to prevent contact with moving parts.
5. The outdoor unit shall have vertical discharge airflow.

C. Refrigerant:

1. R32 or R454B refrigerant shall be used for all systems.
2. Contractor shall provide sufficient refrigerant to properly charge system.

D. Coil:

1. Each outdoor coil shall be of nonferrous construction with lanced or corrugated plate fins on copper tubing.
2. The coil fins shall have a factory applied corrosion resistant blue-fin finish.

3. The coil shall be protected with an integral metal guard.
4. Refrigerant flow from the outdoor unit shall be controlled by means of an inverter driven compressor.
5. The outdoor coil shall include 4 circuits with two position valves for each circuit, except for the last stage.

E. Compressor:

1. Each outdoor unit module shall be equipped with one inverter driven scroll hermetic compressor. Non inverter-driven compressors shall not be allowed.
2. A crankcase heater(s) shall be factory mounted on the compressor(s).
3. The outdoor unit compressor shall have an inverter to modulate capacity. The capacity shall be completely variable with a turndown of 19%-5% of rated capacity, depending upon unit size.
4. The compressor will be equipped with an internal thermal overload.
5. The compressor shall be mounted to avoid the transmission of vibration.
6. Field-installed oil equalization lines between modules are not allowed. Prior to bidding, manufacturers requiring equalization must submit oil line sizing calculations specific to each system and module placement for this project.

F. Electrical:

1. The outdoor unit electrical power shall be 460 volts, 3-phase, 60 hertz.
2. The outdoor unit shall be capable of satisfactory operation within voltage limits of 414-506V (460V/60Hz).
3. The outdoor unit shall be controlled by integral microprocessors.
4. Provide all manufacturer required control wiring between each unit outdoor unit and system controller. Control wiring shall be 2 conductor twisted pair shielded cable.

G. Multiple Condensing Unit Sections:

1. The outdoor unit shall be completely factory assembled, piped and wired. Dual and triple frame outdoor units will be field piped with factory designed and supplied Y-branch kits to manifold them together into a single refrigerant circuit.
2. The outdoor unit shall be modular in design and should allow for side-by-side installation with minimal spacing.
3. Multiple modules shall have duty cycling function to ensure sequential starting of each module at each start/stop cycle, completion of oil return, completion of defrost or every 8 hours of runtime.

2.2 BRANCH CIRCUIT (BC) CONTROLLERS / HEAT RECOVERY BOXES / SOLENOID VALVE KITS

A. General: Unit manufacturer shall provide branch circuit controller / heat recovery box / or solenoid valve kit as required by system to allow for simultaneous heating or cooling operation of any indoor fan coil unit.

B. The BC (Branch Circuit) Controllers shall be specifically used with manufacturer provided fan coil units. These units shall be equipped with a circuit board that interfaces to the VRF controls system and shall perform all functions necessary for operation. The unit shall have a galvanized steel finish. The BC Controller shall be completely factory assembled, piped and wired. Each unit shall be run tested at the factory. This unit shall be mounted indoors, with access and service clearance provided for each controller. The sum of connected capacity of all indoor air handlers shall range from 50% to 150% of rated capacity.

1. BC Unit Cabinet:

    a. The casing shall be fabricated of galvanized steel.
    b. Each cabinet shall house a liquid-gas separator and multiple refrigeration control valves.
    c. The unit shall house two tube-in-tube heat exchangers.

2. Refrigerant: R-32 refrigerant shall be required.
3. Refrigerant valves:

    a. The unit shall be furnished with multiple branch circuits which can individually accommodate up to 54,000 BTUH and up to three indoor units. Branches may be twinned to allow more than 54,000 BTUH.
    b. Each branch shall have multiple two-position valves to control refrigerant flow.
    c. Service shut-off valves shall be field-provided/installed for each branch to allow service to any indoor unit without field interruption to overall system operation.
    d. Linear electronic expansion valves shall be used to control the variable refrigerant flow.

4. See drawings for required quantity of zones for each system. All system alternate manufacturers shall provide identical quantity of cooling and heating zones per BC controller as shown on drawings. If alternate manufacturer unable to provide identical quantity then manufacturer shall provide additional BC controllers, wiring, and piping to provide same number of zones shown on the drawings at no additional cost.
5. Integral Drain Pan: An integral condensate pan and drain shall be provided.
6. Electrical:

    a. The unit electrical power shall be 208/230 volts, 1 phase, 60 hertz.
    b. The unit shall be capable of satisfactory operation within voltage limits of 187-228 volts (208V/60Hz) or 207-253V (230V/60Hz).

7. The BC Controller shall be controlled by integral microprocessors.
8. The control circuit between the indoor units and the outdoor unit shall be 24VDC completed using a 2-conductor, twisted pair shielded cable to provide total integration of the system.

2.3 WALL-MOUNTED INDOOR UNIT

A. General: Unit shall be a wall-mounted indoor unit section and shall have a modulating linear expansion device and a flat front. Unit shall support individual control using manufacturer provided DDC controller.

B. Indoor Unit: The indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, an auto restart function, and a test run switch. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory.

C. Unit Cabinet:

1. All casings, regardless of model size, shall have the same white finish
2. Multi directional drain and refrigerant piping offering four (4) directions for refrigerant piping and two (2) directions for draining shall be standard.
3. There shall be a separate back plate which secures the unit firmly to the wall.

D. Fan:

1. The indoor fan shall be an assembly with one or two line-flow fan(s) direct driven by a single motor.
2. The indoor fan shall be statically and dynamically balanced to run on a motor with permanently lubricated bearings.
3. A manual adjustable guide vane shall be provided with the ability to change the airflow from side to side (left to right).
4. A motorized air sweep louver shall provide an automatic change in airflow by directing the air up and down to provide uniform air distribution.

E. Filter: Return air shall be filtered by means of an easily removable, washable filter.

F. Coil:

1. The indoor coil shall be of nonferrous construction with smooth plate fins on copper tubing.
2. The tubing shall have inner grooves for high efficiency heat exchange.
3. All tube joints shall be brazed with phos-copper or silver alloy.
4. The coils shall be pressure tested at the factory.
5. A condensate pan and drain shall be provided under the coil.
6. Both refrigerant lines to indoor unit shall be insulated.

G. Electrical:

1. The unit electrical power shall be 208/230 volts, 1-phase, 60 hertz.
2. The system shall be capable of satisfactory operation within voltage limits of 187-228 volts (208V/60Hz) or 207-253 volts (230V/60Hz)

H. Controls:

1. This unit shall use controls provided by manufacturer to perform functions necessary to operate the system.
2. The unit shall be able to control external backup heat.
3. The unit shall have a factory built in receiver for wireless remote control.

I. Condensate Pump: Unit manufacturer shall provide condensate pump to lift condensate a minimum of 80". Condensate pump shall be integral to unit or wired through low voltage circuit of unit. Contractor shall provide all wiring and installation for pumps not integral to unit.

2.4 4-WAY CEILING-RECESSED CASSETTE WITH GRILLE INDOOR UNIT

A. General: Unit shall be a four-way cassette style indoor unit that recesses into the ceiling with a ceiling grille. The indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, an auto restart function, an emergency operation function, a test run switch, and the ability to adjust airflow patterns for different ceiling heights. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory.

B. Unit Cabinet:

1. The cabinet shall be space-saving ceiling-recessed cassette.
2. The cabinet panel shall have provisions for a field installed filtered outside air intake.
3. Branch ducting shall be allowed from cabinet.
4. Four-way grille shall be fixed to bottom of cabinet allowing two, three or four-way blow.
5. The grille vane angles shall be individually adjustable from the wired remote controller to customize the airflow pattern for the conditioned space

C. Fan:

1. The indoor fan shall be an assembly with a turbo fan direct driven by a single motor.
2. The indoor fan shall be statically and dynamically balanced to run on a motor with permanently lubricated bearings.
3. The indoor fan shall consist of five (5) speed settings, Low, Mid1, Mid2, High and Auto.
4. The fan shall have a selectable Auto fan setting that will adjust the fan speed based on the difference between controller set-point and space temperature.
5. The indoor unit shall have an adjustable air outlet system offering 4-way airflow, 3-way airflow, or 2-way airflow.
6. The indoor unit shall have switches that can be set to provide optimum airflow based on ceiling height and number of outlets used.
7. The indoor unit vanes shall have 5 fixed positions and a swing feature that shall be capable of automatically swinging the vanes up and down for uniform air distribution.

8. The vanes shall have an Auto-Wave selectable option in the heating mode that shall randomly cycle the vanes up and down to evenly heat the space.
9. The grille shall have an optional “i-see” sensor that will measure room temperature variations and adjust the airflow accordingly to evenly condition the space.

D. Filter: Return air shall be filtered by means of a long-life washable filter.

E. Coil:

1. The indoor coil shall be of nonferrous construction with smooth plate fins on copper tubing.
2. The tubing shall have inner grooves for high efficiency heat exchange.
3. All tube joints shall be brazed with phos-copper or silver alloy.
4. The coils shall be pressure tested at the factory.
5. A condensate pan and drain shall be provided under the coil.
6. Both refrigerant lines to the indoor unit shall be insulated.

F. Condensate Pump: The unit shall be provided with an integral condensate lift mechanism that will be able to raise drain water 33 inches above the condensate pan.

G. Electrical:

1. The unit electrical power shall be 208/230 volts, 1-phase, 60 hertz.
2. The system shall be capable of satisfactory operation within voltage limits of 187-228 volts (208V/60Hz) or 207-253 volts (230V/60Hz).

H. Controls: This unit shall use controls provided by unit manufacturer to perform functions necessary to operate the system.

2.5 CEILING-CONCEALED DUCTED INDOOR UNIT

A. General: Unit shall be a ceiling-concealed ducted indoor fan coil design that mounts above the ceiling with a 2-position, field adjustable return and a fixed horizontal discharge supply and shall have a modulating linear expansion device.

B. Indoor Unit. The indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, and an auto restart function. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory.

C. Unit Cabinet:

1. The unit shall be, ceiling-concealed, ducted.
2. The cabinet panel shall have provisions for a field installed filtered outside air intake.

D. Fan:

1. Unit shall feature external static pressure settings from 0.14 to 0.60 in. WG.
2. The indoor unit fan shall be an assembly with one or two Sirocco fan(s) direct driven by a single motor.
3. The indoor fan shall be statically and dynamically balanced and run on a motor with permanently lubricated bearings.
4. The indoor fan shall consist of three (3) speeds, High, Mid, and Low plus the Auto-Fan function
5. The indoor unit shall have a ducted air outlet system and ducted return air system.

E. Filter:

1. Return filter box (rear or bottom placement) with 1” 30 % MERV 8 high-efficiency filter.
2. Provide clean set of filters and one spare set of filters at substantial completion

F. Coil:

1. The indoor coil shall be of nonferrous construction with smooth plate fins on copper tubing.
2. The tubing shall have inner grooves for high efficiency heat exchange.
3. All tube joints shall be brazed with phos-copper or silver alloy.
4. The coils shall be pressure tested at the factory.
5. A condensate pan and drain shall be provided under the coil.
6. The condensate shall be gravity drained from the fan coil.
7. Both refrigerant lines to the indoor unit shall be insulated.

G. Condensate Pump: Unit manufacture shall provide condensate lift mechanism to lift condensate a minimum of 21”.

H. Electrical:

1. The unit electrical power shall be 208/230 volts, 1-phase, 60 hertz.
2. The system shall be capable of satisfactory operation within voltage limits of 187-228 volts (208V/60Hz) or 207-253 volts (230V/60Hz).

I. Controls: This unit shall use controls provided by unit manufacturer to perform functions necessary to operate the system.

2.6 LOW PROFILE CEILING-CONCEALED DUCTED INDOOR UNIT

A. General: The Low Profile unit shall be a ceiling-concealed ducted indoor fan coil that mounts above the ceiling with a rear return and a fixed horizontal discharge supply and shall have a modulating linear expansion device. Low Profile models shall have an extremely compact profile 7-7/8” which requires minimal ceiling space. Unit shall feature external static pressure settings up to 0.20 in. WG. Units shall have the ability to control supplemental heat via connector CN24 and a 12 VDC output.

B. Indoor Unit: The indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, and an auto restart function. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory.

C. Unit Cabinet:

1. The cabinet shall be space saving, low profile, ceiling-concealed ducted.
2. The cabinet panel shall have provisions for a field installed filtered outside air intake.

D. Fan:

1. The indoor unit fan shall be an assembly with one Sirocco fan direct driven by a single motor.
2. The indoor fan shall be statically and dynamically balanced to run on a motor with permanently lubricated bearings.
3. The indoor fan shall consist of three (3) speeds, High, Mid, and Low.
4. The indoor unit shall have a ducted air outlet system and ducted return air system.

E. Filter: Return air shall be filtered by means of a replacable 1” 30 % MERV 8 return air filter. Provide one set of clean and one spare set of filters at substantial completion

F. Coil:

1. The indoor coil shall be of nonferrous construction with smooth plate fins on copper tubing.
2. The tubing shall have inner grooves for high efficiency heat exchange.
3. All tube joints shall be brazed with phos-copper or silver alloy.
4. The coils shall be pressure tested at the factory.
5. A condensate pan and drain shall be provided under the coil.
6. Both refrigerant lines to the indoor unit shall be insulated.

G. Condensate Pump: The unit shall be provided with an integral condensate lift mechanism able to raise drain water 21 inches above the condensate pan.

H. Electrical:

1. The unit electrical power shall be 208/230 volts, 1 phase, 60 hertz.
2. The system shall be capable of satisfactory operation within voltage limits of 187-228 volts (208V/60Hz) or 207-253 volts (230V/60Hz).

I. Controls: This unit shall use controls provided by unit manufacturer to perform functions necessary to operate the system. .

2.7 HIGH STATIC CEILING-CONCEALED DUCTED INDOOR UNIT

A. General: High Static unit shall be a ceiling concealed ducted indoor fan coil that mounts above the ceiling with a fixed rear return and a horizontal discharge supply, and shall have a modulating linear expansion device. Unit shall feature external static pressure settings up 0.80 in. WG. Units shall have the ability to control supplemental heat via connector CN24 and a 12 VDC output.

B. Indoor Unit: The indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, and an auto restart function. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory.

C. Unit Cabinet:

1. The cabinet shall be ceiling-concealed, ducted.
2. The cabinet panel shall have provisions for a field installed filtered outside air intake.

D. Fan:

1. The indoor unit fan shall be an assembly with one or two Sirocco fan(s) direct driven by a single motor.
2. The indoor fan shall be statically and dynamically balanced to run on a motor with permanently lubricated bearings.
3. The indoor unit shall have a ducted air outlet system and ducted return air system.

E. Filter: Provide rear return filter box with 1” 30% efficient MERV 8 replaceable filter. Provide clean set of filters and one spare set of filters at substantial completion.

F. Coil:

1. The indoor coil shall be of nonferrous construction with smooth plate fins on copper tubing.
2. The tubing shall have inner grooves for high efficiency heat exchange.
3. All tube joints shall be brazed with phos-copper or silver alloy.
4. The coils shall be pressure tested at the factory.
5. A condensate pan and drain shall be provided under the coil.
6. Both refrigerant lines to the indoor unit shall be insulated.

G. Condensate Pump: Unit manufacture shall provide condensate lift mechanism to lift condensate a minimum of 21”.

H. Electrical:

1. The unit electrical power shall be 208/230 volts, 1-phase, 60 hertz. or 208/230 volts, 3-phase, 60 hertz as scheduled on drawings.
2. The system shall be capable of satisfactory operation within voltage limits of 187-228 volts (208V/60Hz) or 207-253 volts (230V/60Hz).

I. Controls: This unit shall use controls provided unit manufacturer to perform functions necessary to operate the system.

2.8 CEILING-SUSPENDED INDOOR UNIT

A. General: Unit shall be ceiling-suspended indoor unit section and have a modulating linear expansion device. Unit shall support individual control using manufacturer provided controllers.

B. Indoor Unit: The indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, an auto restart function, and a test run switch. The unit shall have an auto-swing function for the horizontal vane. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory.

C. Unit Cabinet: The casing shall have a white finish.

D. Fan:

1. The indoor unit fan shall be an assembly with two, three, or four Sirocco fan(s) direct driven by a single motor.
2. The indoor fan shall be statically and dynamically balanced to run on a motor with permanently lubricated bearings.
3. The indoor fan shall consist of four (4) speeds, Low, Mid1, Mid2, and High, and Auto fan function.

E. Filter: Return air shall be filtered by means of an easily removable, washable filter.

F. Coil:

1. The indoor coil shall be of nonferrous construction with smooth plate fins on copper tubing.
2. The tubing shall have inner grooves for high efficiency heat exchange.
3. All tube joints shall be brazed with phos-copper or silver alloy.
4. The coils shall be pressure tested at the factory.
5. A condensate pan and drain shall be provided under the coil.
6. Both refrigerant lines to unit shall be insulated.

G. Condensate Pump: Unit manufacture shall provide condensate lift mechanism to lift condensate a minimum of 21”.

H. Electrical:

1. The unit electrical power shall be 208/230 volts, 1 phase, 60 hertz.
2. The system shall be capable of satisfactory operation within voltage limits of 187-228 volts (208V/60Hz) or 207-253 volts (230V/60Hz)

I. Controls:

1. This unit shall use controls provided by unit manufacturer to perform functions necessary to operate the system.
2. Units shall have the ability to control supplemental heat via connector CN24 and a 12 VDC output

2.9 CONTROLS

A. General:

1. The unit shall have controls provided with the unit by the manufacturer to perform input functions necessary to operate the system.
2. Computerized PID control shall be used to maintain room temperature within 1 F of setpoint.
3. The unit shall be equipped with a programmed drying mechanism that dehumidifies while inhibiting changes in room temperature.
4. The fan coil circuit board shall be wired to enable auxiliary heating when coil thermistor temperature drops below 104 degrees F in heating mode.

2.10 CONTROLLERS

A. Physical Characteristics: General: control system devices shall be a neutral color plastic material with a Liquid Crystal Display (LCD).

B. Electrical Characteristics:

1. General: From each circuit board to the controls, the electrical voltage shall be low voltage.
2. Wiring: Control wiring shall be installed in a daisy chain configuration from indoor unit to indoor unit then to the outdoor unit. Control wiring shall run from the indoor unit terminal block to the specific controller for that unit.
3. Wiring Size: The wire shall be a shielded, size AWG18-2.

2.11 INDIVIDUAL ZONE CONTROLLER – WIRED REMOTE CONTROLLER

A. The wired remote controller shall be able to control 1 group (maximum of 16 fan coil units) and shall be able to function as follows:

1. The controller shall have a self diagnosis function that constantly monitors the system for malfunctions (total of 80 components).
2. The controller shall be able to immediately display fault location and condition.
3. An LCD digital display shall allow the temperature to be set in 1 degree Fahrenheit units.
4. The controller shall be equipped with a thermostat sensor in the remote controller making possible more comfortable room temperature control.

B. The wired remote controller shall have the following features:

1. Operation: Start/Stop, Operation Mode, Temperature Setting, 60 degrees Fahrenheit - 90 degrees Fahrenheit, Set Point Range, Fan Speed, Airflow Direction.
2. Monitoring: Status, malfunction flashing, malfunction content, filter sign, operation mode, temperature setting, permit/prohibit selection, fan speed, airflow direction.
3. Scheduling: ON/OFF Timer
4. Control Management: Field Setting Mode, Group Setting, Auto Re-start
5. The controller shall also be able to switch an external dry contact via a 12 volt DC relay (field supplied).

2.12 INDIVIDUAL ZONE CONTROLLER – SIMPLIFIED WIRED REMOTE CONTROLLER

A. The simplified wired remote controller shall be able to control 1 group (maximum of 16 fan coil units).

B. The simplified wired remote controller shall have the following features:

1. Operation: Start/Stop, Operation Mode, Temperature Setting, 60 degrees Fahrenheit – 90 degrees Fahrenheit Set Point Range, Fan Speed, Airflow Direction.
2. Monitoring: Status, malfunction flashing, malfunction content, filter sign, operation mode, temperature setting, permit/prohibit selection, fan speed, airflow direction.
3. Scheduling: ON/OFF Timer
4. Control Management: Field Setting Mode, Group Setting, Auto Re-start

2.13 SYSTEM REMOTE CONTROLLER

A. The controller shall control up to 64 units in 4 zones and shall be able to be used in conjunction with all room controller types. Provide as many system controllers as required to control the system. Collective and individual group commands are available with permit/prohibit individual remote controller function.. The system controller shall use the following connections for power and remote monitoring:

1. L1: Power supply (60 Hz, 208-230 VAC)
2. C1: Inter-unit control wiring (Low voltage)
3. C3: Auxiliary

4. C4: Ground for inter-unit control wiring
5. A1: Input for turning ON air conditioners concurrently
6. A2: Input for turning OFF air conditioners concurrently
7. A3: Common input for turning air conditioners ON or OFF
8. B1: On operation state indicator output
9. B2: Alarm indicator output
10. B3: Common indicator output

2.14 WEB ENABLED INTELLIGENT CONTROLLER

A. This controller shall be wall mounted and hard wired, either directly to the VRF control system or via RS485 gateway. It will be manufactured in ABS plastic with an LCD display and will be the manufacturer's standard color. The controller will be capable of individually controlling the following functions on 256 indoor fan coil units:

1. On/off.
2. Operating mode.
3. Set point.
4. Fan speed.
5. Louver position.
6. Timer settings.
7. Test run.

B. The controller shall also be capable of displaying the following information individually for 256 indoor fan coil units:

1. On/off.
2. Operating mode.
3. Set point.
4. Fan speed.
5. Louver position.
6. Timer settings.
7. Test run.
8. Fault diagnosis.

C. Each Intelligent controller unit can be accessed either locally or remotely via standard Internet Explorer IE6 or IE7 software. The Intelligent controller will be able to indicate system alarms via volt free contacts as well as providing control points for other D0 devices. Additionally, the intelligent controller shall be able to monitor individual tenant's usage of heating and cooling demands, report alarm and conditions to nominated email address, and enable remote alteration of systems set points to registered users.

2.15 GATEWAY:

A. Provide BACnet or LONworks Gateway to fully interface system function into building DDC control system. Manufacturer shall coordinate gateway requirements with control contractor prior to bid.

PART 3 EXECUTION

3.1 INSTALLATION

A. Installation, Operation and Maintenance manual shall be supplied with the unit.

B. Installing contractor shall install unit, including field installed components, in accordance with Installation, Operation and Maintenance manual instructions. All refrigerant piping shall be ACR hard drawn copper with brazed joints. Flared fittings will not be acceptable. Installation must be per the manufacturer's piping tree diagram for the project. Before any pipe or length changes are made, proposed changes must be forwarded to the manufacturer's engineering representative and manufacturer's new piping tree diagram re-issued for installation, because any change made requires the review of the entire tree and verification that the change did not impact the size of piping segments in other parts of the system. No oil traps, solenoid valves, sight glasses, filter dryers, or any other unauthorized refrigerant specialties are to be used.

C. Start up and maintenance requirements shall be complied with to ensure safe and correct operation of the unit. Engage manufacturer or factory-authorized service representative to perform startup service. Manufacturer shall provide on-site startup and commissioning assistance through job completion. Complete installation and startup checks according to manufacturer's written instructions.

D. Unit manufacturer to provide services of factory trained personnel to verify operation of system installation and control hardware.

E. Provide all labor, refrigerant, and material required for a complete installation. Work to be performed shall be in accord with local codes, regulations, and OSHA standards.

F. Install all piping, fittings, and insulation to meet manufacturer's requirements. Install units level and plumb. Evaporator-fan components shall be installed using manufacturer's standard mounting devices securely fastened to building structure. Install and connect refrigerant tubing and fittings.

G. All lines from outdoor unit to BC controller / heat recovery box and all lines from BC controller to indoor fan coil unit shall be insulated. Refer to Section 23 0710 Insulation for specific requirements.

H. Installer shall supply isolation ball valves for zoned refrigerant isolation. Installer shall supply Isolation ball valves with Schrader connection for isolating refrigerant charge and evacuation at each connected air handling unit and condensing unit. Isolation ball valves, with Schrader connection, are required for instances of air handling unit isolation for troubleshooting, repair or replacement without affecting the remainder of the system. Isolation ball valves with Schrader connection are also required at condensing unit connection to isolate unit for troubleshooting, repair or replacement and as required to provide partial capacity Heating/Cooling in the instance of a failure of one of the multiple outdoor unit (condensing unit) compressors.

I. Contractor shall install and pressure test piping system in accordance with manufactures instructions. Provide written documentation of all pressure tests. Perform the leak/pressure check at 150 psig for (5) five minutes (standing pressure check). Perform the leak/pressure check at 300 PSI for (15) fifteen minutes (second standing pressure check). Perform the leak/pressure check at 550 PSI fir (24) twenty-four hours to make sur ethe system is leak free.

3.2 OWNER TRAINING

A. The manufacturer that provides the VRV system for this project will include in his price the cost to have a “Factory Service Representative” provide onsite training for the VRV system to include, but not limited to:

1. System rebooting.
2. Identifying error codes.
3. Resetting filter indicators.
4. Basis system operation.
5. Explanation of service indicators.
6. How the manufacturer can support with system issues.

B. This training will be a minimum of:

1. 8 hours during equipment startup.
2. 8 hours at Substantial Completion.
3. 8 hours and the end of the Manufacturer Warranty period.

C. Training shall be by a representative from the Factory. Training by local sales representative is not acceptable.

D. Prior to beginning of training, Manufacturer shall provide written material and outline of training for approval by Owner, Cx agent, and design team.

E. Contractor shall schedule training in advance with Owner.

END OF SECTION 23 7556

SECTION 23 81 23 - COMPUTER ROOM AIR-CONDITIONING UNIT

PART 1 GENERAL

1.1 MANUFACTURES AND UNIT TYPE

A. Computer room air-conditioning unit to be UL or ETL listed direct expansion self-contained, factory assembled unit.

B. Units to be Liebert or approved equal.

PART 2 PRODUCTS

2.1 INDOOR UNIT

A. Construct frame of heliarc welded tubular steel or minimum 1-1/2" angles with interior steel welded to frame assembly. Insulate cabinet interior with minimum 1" thick, 1-1/2 lb/cu. ft. glass fiber insulation. Construct exterior panels of furniture steel and provide concealed fasteners and hinges. Frame shall be capable of being separated into several parts for rigging through small spaces. Provide front access doors for full unit service from front.

1. Unit to be down discharge airflow with top return pattern unless otherwise indicated on drawings.

B. Statically and dynamically balanced, single inlet plug/plenum type centrifugal fans. Drive package shall be direct drive, electronically commutated variable speed motors. Support fan wheels on a heavy duty shaft having self aligning ball bearings with a 100,000 hour minimum life span.

C. Provide minimum 4" thick, MERV 8 disposable filters integral with unit.

D. Provide A-frame cooling coil with copper tubes and aluminum fins with a maximum spacing of 12 fins/inch. Mount coil assembly in a condensate drain pan constructed of stainless steel.

E. Provide two separate refrigerant circuits each including semi-hermetic, digital scroll compressors, hot gas muffler, liquid line filter dryer, refrigerant sight glass with moisture indicator, adjustable, externally equalized expansion valve, and liquid line solenoid valve. Compressors shall be provided with suction gas-cooled motor, vibration isolators, thermal overloads, oil sight glass, high-pressure switch, low-pressure switch, suction line strainer, reversible oil pump for forced feed lubrication, and maximum 3500 RPM operating speed. Provide 5-year compressor warranty. Provide cylinder unloaders on each compressor to provide four-step system.

F. Provide electric power panel complete with contactors, transformers, overloads, and all other electrical components. Each system component to be protected by a separate over-current protection device. Provide locking type disconnect switch.

2.2 OUTDOOR UNIT

A. Provide factory wired and piped air-cooled condenser suitable for remote mounting. Air-cooled condenser to be complete with aluminum microchannel coils, direct drive ECM propeller fans, integral electric control panel with disconnect switch, and weatherproof fan motors with ball bearings, permanent lubrication, and internal overload protection.

B. Provide low-ambient control for winter operation down to 0 degrees F ambient.

C. Provide refrigerant economizer system. Refrigerant pumps to be variable-speed, one per circuit, controlled by individual VFDs. Package to be factory wired, piped, and tested refrigerant piping within a NEMA 3R enclosure. Economizer package can be waived if split system efficiency exceeds 2023 Florida Energy Code by 17% as tested by AHRI 1360.

2.3 CONTROL SYSTEM

A. Provide microprocessor control system with digital display monitor panel. Control system shall provide for local monitoring and programming of these points: current temperature, temperature setpoint, temperature sensitivity, current humidity, humidity setpoint, and humidity sensitivity. Control system shall indicate control operating mode(s) on the monitor panel.

B. Control system shall monitor unit operation and activate an audible and visual alarm in the event of the following alarm conditions: high temperature, low temperature, high humidity, low humidity, high head pressure, change filters, and loss of air. Provide silence switch for audible alarm.

C. Control system shall provide lead/lag compressor sequencing to equalize the usage of the compressors. Control system shall command sequencing with the outdoor unit and economizer package as necessary to meet indoor load requirements.

D. Control system shall be capable of communicating with multiple units within the same space. The controller shall operate units in parallel, by designating one unit as the Master unit and controlling operating modes of other units. Temperature control parameters shall be user definable between average or worst case.

E. Provide the following additional control system features:

1. Smoke detector.
2. General alarm contact for remote indication at central building automation system.

3. RS-485 and CAT6 port and software to permit complete monitoring and programming from central building automation system.

2.4 ACCESSORIES

A. Provide the following accessories:

1. Floor stand.
2. Condensate pump.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install unit in strict accordance with manufacturers' published installation instructions.

B. Install unit to maintain proper clearances for service.

C. Use caution to ensure piping and cables below elevated floor do not restrict airflow.

END OF SECTION 23 81 23

SECTION 23 81 26 - SPLIT SYSTEM A/C UNITS

PART 1 GENERAL

1.1 WORK INCLUDED

A. Air-cooled, split system air conditioning units to be by Carrier, Trane, York, or specifically approved equal.

B. Manufacturers both listed above and proposed alternates to review the allowable space for the indoor units considering service access, filters access and refrigerant and condensate piping to ensure adequate clearance exists for their units prior to submitting bid. Contractor shall not be allowed an extra should the low bidder prove to have unacceptable clearance.

C. Manufacturer to submit for approval all evaporator and condensing unit matches showing a balance diagram indicating refrigerant suction pressure and proposed refrigerant line sizes. Under no circumstances shall an evaporator/condensing unit match be selected less than 36 degrees F. Attention to be given to units where significant lengths (heights) exist between evaporator and condensing unit locations.

PART 2 PRODUCTS

2.1 CONDENSING UNITS

A. Units to have capacity scheduled on drawings and be complete with the following:

1. Capacitor start and relay.
2. Indoor fan relay.
3. Liquid line filter dryer.
4. Short cycling prevention (Solid State).
5. Solid brass service valves.
6. Crankcase heaters.
7. High and low refrigerant pressure switches.
8. Current and thermal compressor overloads.
9. Winter start and condensing pressure control to allow operation in ambient to 0 degrees F.
10. Fully weatherproof casing, galvanized steel, zinc phosphatized, and finished with enamel. Provide with screened or louvered coil guards.
11. Control transformer.
12. Five-year compressor warranty.
13. Automatic changeover thermostat.

2.2 EVAPORATOR UNIT

A. Units to be capacity matched with condensing units and complete with following:

1. Forward curved, double inlet supply fan mounted on motor shaft, dynamically and statically balanced. Fan motor to be multi-speed, factory lubricated, have internal overload protection, and be resiliently mounted.
2. Cooling coil of nonferrous tubing with mechanically bonded aluminum plate fins with all joints brazed. Coil to have factory installed refrigerant metering device, refrigerant mechanical joint line fittings, and condensate pan.
3. Factory installed electric heater. All heaters to be equipped with thermal overload device, current overload for heaters 10 kw and required heating and cooling system controls including 60-va control circuit 24-volt transformer. Low voltage connection to be point-to- point on terminal board.
4. Factory insulated unit enclosure constructed of cold-rolled steel, bonderized and finished with baked enamel. Front access panels to provide access to all components. Filter rack to accept 1 inch thick filters.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install evaporator and condensing unit to allow space for service, maintenance, and airflow requirements.

B. Provide flexible duct to evaporator connection.

C. Install in compliance with manufacturers' recommendations.

END OF SECTION 23 81 26