

| Section No. | Title | Issue Date |
|--------------------|---|-------------------|
| 23 05 01 | Mechanical General Provisions | 8/18/08 |
| 23 05 05 | Mechanical Scope of Work | 8/18/08 |
| 23 05 13 | Electric Motors | 8/18/08 |
| 23 05 14 | Variable Frequency Drives | 8/18/08 |
| 23 05 16 | Expansion Compensation | 8/18/08 |
| 23 05 19 | Meters, Gauges and Thermometers | 8/18/08 |
| 23 05 23 | Valves | 8/18/08 |
| 23 05 29 | Supports, Hangers, Anchors and Sleeves | 8/18/08 |
| 23 05 48 | Vibration Isolation and Seismic Restraints | 8/18/08 |
| 23 05 50 | Access Doors in General Construction | 8/18/08 |
| 23 05 53 | Systems Identification | 8/18/08 |
| 23 05 93 | Mechanical Systems Balancing | 8/18/08 |
| 23 07 00 | Insulation | 8/18/08 |
| 23 08 01 | General Mechanical Starting and Testing Requirements | 8/18/08 |
| 23 08 11 | Mechanical Equipment – Equipment Starting and Testing | 8/18/08 |
| 23 08 21 | Mechanical Systems Starting and Testing | 8/18/08 |
| 23 08 22 | Systems Commissioning | 8/18/08 |
| 23 09 00 | Building Management System (BMS) | 8/18/08 |
| 23 09 65 | Laboratory Airflow Control System | 10/15/08 |
| 23 09 93 | Automatic Control Sequences | 8/18/08 |
| 23 21 01 | Hydronic Systems Specialties | 8/18/08 |
| 23 21 13 | Piping and Accessories | 8/18/08 |
| 23 21 23 | Pumps | 8/18/08 |
| 23 22 33 | Steam Specialties | 8/18/08 |
| 23 25 00 | Water Treatment | 8/18/08 |
| 23 25 16 | Water Filter and Cyclone Separator | 8/18/08 |
| 23 31 00 | Ductwork | 8/18/08 |
| 23 33 13 | Dampers | 8/18/08 |
| 23 33 19 | Acoustics | 8/18/08 |
| 23 34 00 | Fans | 8/18/08 |
| 23 36 00 | Air Terminal Units | 8/18/08 |
| 23 37 00 | Air Outlets and Inlets | 8/18/08 |
| 23 40 00 | Air Filters and Cleaners | 8/18/08 |
| 23 51 00 | Chimneys and Vents | 8/18/08 |
| 23 52 16 | Gas Fired Condensing Boilers | 8/18/08 |
| 23 52 33 | Packaged Water Tube Steam Boilers | 8/18/08 |

| | | |
|----------|--|---------|
| 23 57 00 | Heat Exchangers | 8/18/08 |
| 23 64 26 | Electric Screw Heat Recovery Liquid Chillers | 8/18/08 |
| 23 65 33 | Fluid Coolers | 8/18/08 |
| 23 73 13 | Factory Assembled Air Handling Units | 8/18/08 |
| 23 73 23 | Custom Air Handling Units | 8/18/08 |
| 23 81 23 | Computer Room Air Conditioning Units | 8/18/08 |

SECTION 23 08 11

MECHANICAL EQUIPMENT – EQUIPMENT STARTING AND TESTING

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. Check, start and test each piece of mechanical equipment. Verify that the equipment has been properly installed and is operating at a level that meets the specified requirements.

1.02 RELATED DOCUMENTS

- A. Section 23 05 01 - General Mechanical Provisions
- B. Section 23 08 01 - General Mechanical Starting and Testing Requirements
- C. Section 23 08 21 - Mechanical Systems Starting and Testing
- D. Section 23 09 00 - Mechanical Systems Balancing

1.03 FACTORY TRAINED REPRESENTATIVES

- A. Use factory trained representatives and submit manufacturer's check sheets for starting the following specialty equipment:
 - 1. Chillers
 - 2. Cooling towers
 - 3. Variable speed drives
 - 4. Building Management System
 - 5. Chemical cleaning and treatment
 - 6. Boilers
- B. Use manufacturer's factory trained personnel where required to maintain manufacturer's warranties.

1.04 FIELD REPORTS

- A. Submit field reports documenting the starting and testing procedures performed, observations and tests results obtained.
- B. Submit field reports in accordance with Section 23 05 01 - Mechanical General Provisions.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

3.01 FLUID HANDLING EQUIPMENT

- A. Pumps:
 - 1. Pre-Starting:

- a. Compare specified and shop drawing data to installed data, including:
 - (1) Make/model/size
 - (2) Impeller size
 - (3) Seal type
 - (4) Lubrication fittings
 - (5) Motor size, speed, efficiency, and voltage
 - (6) Flow gallons per minute (gallons per minute)
 - (7) Head feet of water column (feet water column)
- b. Ensure pump installation is as specified and as per manufacturer's recommendations. Fill out manufacturer's check sheet including:
 - (1) Pump is level.
 - (2) Isolation valves, strainers, check valves are installed properly.
 - (3) Pump suction has sufficient length of straight run.
 - (4) Air is completely bled off piping system.
 - (5) Expansion tank is charged and on-line.
 - (6) Ensure strainers have screens in place and are clean.
 - (7) Ensure electrical connections are properly made.
 - (8) Ensure nameplate is readily visible.
 - (9) Check clearance space adequately permits removal or servicing.
 - (10) Check voltage to pump motor.
- c. Ensure chemical cleaning of piping system is completed.
- d. Check and adjust oil levels bearing lubrication.

2. Starting:

- a. Start pumps as per manufacturer's recommendations.
- b. Ensure impeller and motor are rotating in the correct direction.

3. Post Starting:

- a. Check chemical treatment status.
- b. Run-in pumps for minimum 12 continuous hours.
- c. Ensure flows through parallel pumps are equally balanced.
- d. Record motor power consumption.
- e. Ensure mechanical seals do not leak. Ensure packing gland type seals are wetted.
- f. Calculate overall pump efficiency.
- g. Calculate/check net positive suction head.
- h. Verify the motor has sufficient airflow around to allow cooling.
- i. Plot operating point at time of starting on pump curve.

4. Pre-Interim Acceptance:

~~a. Change pump seals.~~

- a. Clean strainers.

~~c. Trim pump impeller at the factory and verify flows, based upon information recorded and documented during balancing and adjusting.~~

B. Heat Exchangers:

1. Pre-Starting:

- a. Compare specified and shop drawing data to the installed data including:
 - (1) Make/model/size

- (2) Nameplate heat output/input
- (3) Nameplate flows
- (4) Cooling media
- (5) Cooled media
- (6) Pressure rating – nameplate
- (7) Clearances:
 - (a) Plate removal
 - (b) Flanged inlet/outlet
- (8) Piping connections:
 - (a) PRVs – piped to drain
 - (b) Inlet/outlet sizes – cooling medium
 - (c) Inlet/outlet sizes – cooled medium
- (9) Labels – ASME, UL, OSHA
- (10) Vacuum breaker on connection to water supply

b. Visually check for the following:

- (1) Piping completed.
- (2) System cleaning executed.
- (3) Circulating pump starting completed.
- (4) Cooling pumps starting completed.
- (5) Unit clean of foreign matter – remove heads as required.
- (6) Control valve in operation.
- (7) Insulation complete.

2. Starting: Not applicable.

3. Post-Starting:

a. Check/calculate the following:

- (1) Inlet/outlet flow rates
- (2) Inlet/outlet temperatures
- (3) Inlet/outlet pressure

b. Ensure sufficient load on system and that cooling medium is at design temperatures as follows:

- (1) Cooling medium flow and temperature drop
- (2) Cooled medium flow and temperature drop
- (3) Calculate heat transfer from cooling medium
- (4) Calculate heat transfer from cooled medium

c. Simulate cooling water schedule and repeat above items.

d. Pre-Interim Acceptance: Not applicable.

C. Closed Circuit Cooling Towers:

1. Pre-Starting:

a. Compare specified and shop drawing data to the installed data including:

- (1) Make/model/size
- (2) Fan motor size, efficiency and speed options, electrical consumption

- (3) Accessories including access ladder
- (4) Control sequences
- (5) Construction

b. Prior to starting, perform the following:

- (1) Clean entire unit and wash down basins.
- (2) Ensure all accessories are properly installed.
- (3) Check motor at all stages of capacity overloads on all 3 leads.
- (4) Lubricate motor bearings and check motor insulation.
- (5) Check fan for freely rotating wheel and for blade tip clearance.
- (6) Check water make-up float and level controls.
- (7) Check for clearance of airflow and service.
- (8) Check oil level in gear reducer.
- (9) Check for isolation and structural support.
- (10) Ensure chemical treatment is properly working.
- (11) Ensure water meters are properly working.
- (12) Verify water level in multiple cell cooling towers are equalized.

2. Starting:

- a. Start as per the manufacturer's recommendations.
- b. Fill out manufacturer's check sheets.
- c. Post-Starting:

- (1) Check fan is rotating in correct direction.
- (2) Check water level.
- (3) Check for chemical treatment levels.
- (4) With unit running on low speed and on high speed, provide radiated acoustical measurements on both faces, space directly beneath unit, and from 50 feet away on all four sides.

d. Pre-Interim Acceptance:

- (1) Check tower for proper basin water level.
- (2) Check and document chemical treatment level.

D. Chillers:

1. Pre-Starting:

a. Compare specified and shop drawing data to the installed data including:

- (1) Make/model/size
- (2) Capacity of cooling
- (3) Chilled water: flow, pressure drop, temperature
- (4) Condenser water: flow, pressure drop, temperature
- (5) Tube fouling factors
- (6) Refrigerant
- (7) Motor size, voltage, and full load amperes

b. After installation check the following:

- (1) No physical damage to chiller or insulation has occurred during construction.
- (2) Chiller is level.
- (3) Vibration isolators and seismic restraints are properly installed.
- (4) Water connections allow dismantling and tube servicing.
- (5) Vibration isolation on water piping installed.

- (6) Oil levels are as per manufacturer's recommendations.
- (7) Refrigerant charge is sufficient and leak tested.
- (8) Shipping skids/blocks/straps are removed.
- (9) Adequate space for servicing.
- (10) Chiller has adequate ventilation.
- (11) Chiller relief piping is properly vented to outside per code.
- (12) Water piping completed and cleaned.
- (13) Thermometers, pressure gauges installed.
- (14) Control systems complete:

- (a) Temperature sensors placed in proper locations.
- (b) Flow switch installed.

- (15) Pumps completed starting procedure.
- (16) Electrical wiring completed and approved.
- (17) Motor overloads installed.
- (18) Oil cooler piping installed and insulated.

c. Obtain from manufacturer, the following:

- (1) Correction tables for varying condenser water temperatures
- (2) Correction tables for varying chilled water temperatures
- (3) Check sheets

d. Starting of chillers shall be performed by manufacturer using factory-trained personnel.

2. Starting:

- a. Start as per manufacturer's instructions.
- b. Fill out starting sheets and attach copy with reports.

3. Post-Starting:

- a. Run-in chiller as per manufacturer's recommendations.
- b. Measure the following items under 25, 50 and 75 percent part load and maximum load conditions:

- (1) Condenser water temperature in/out
- (2) Chilled water temperature in/out

- c. Check deflection of isolators on start-up and shutdown.
- d. Report any condensation due to lack of insulation.
- e. Pre-Interim Acceptance:

- (1) Check refrigerant charge
- (2) Check oil levels

E. Miscellaneous Fluid Handling Equipment:

- 1. Confirm all gauges and thermometers can be read from the floor level and they are installed as per manufacturer's recommendations.
- 2. Verify the following equipment is installed and calibrated as per manufacturer's recommendations. Fill out manufacturer's start-up sheets:

- a. PRVs
- b. Air eliminator
- c. Strainers

- d. Check valves
- e. Balancing valves

3.02 AIR HANDLING EQUIPMENT

A. Air Handling Units:

1. Pre-Starting:

- a. Compare specified and shop drawings data to installed data including:
 - (1) Make/model/size
 - (2) Fan wheel size
 - (3) Nameplate flow, static pressure
 - (4) Motor size, speed, efficiency, type, and voltage
 - (5) Heating coil, cooling coil
 - (6) Humidifier
 - (7) Mixing baffles
 - (8) Return, exhaust and outside air motorized dampers, operation and size
 - (9) Filters
 - (10) Vibration isolation, flexible connections and seismic restraints (internal and external)
 - (11) Special features – access doors, liners, inlet vanes, labels
 - (12) Ensure variable speed drive is operational
 - (13) Ensure silencers are installed
- b. Lubricate bearings on fans as per manufacturer's recommendations. Ensure fan wheel rotates smoothly without binding. Adjust belts to proper alignment and tension.
- c. Vacuum out air system plenums and ductwork.
- d. Ensure temporary filters are installed. Under no circumstances run systems without filters installed.
- e. Ensure all balancing and fire/smoke dampers are open and ductwork is complete. For VAV systems, ensure that at least 60 percent of terminal units are open.
- f. Ensure minimum position specified for terminal units are properly set.
- g. Ensure all coils are in operation.
- h. On parallel fan systems, ensure backdraft dampers are installed.
- i. Ensure electrical connections are completed and system disconnects are within visual access of unit.
- j. Ensure controls are operational.
- k. Ensure inlet and discharge duct geometry are properly installed.

2. Starting:

- a. Follow manufacturer's recommendations.
- b. Check fan and motor for correct rotation.

3. Post-Starting:

- a. Check vibration isolation and seismic restraints.
- b. Check radiated and discharge acoustics at design conditions.
- c. Run for one hour and check filters, coils, and humidifier bypass. Seal as required.
- d. Determine fan speed, airflow rates, static pressure and record on fan curve.
- e. Effectiveness of mixing chamber. Measure temperature profile. Adjust mixing baffles.

- f. Balance water flow across humidifier and ensure water treatment is operational.
4. Pre-Interim Acceptance:
- a. Replace temporary filters with permanent filters.
 - b. Vacuum heating coil and cooling coil.
 - c. Re-lubricate all bearings.
 - d. Perform acoustical measurements of discharge plus radiated levels at operating conditions after entire system is operational.
 - e. Check belt for tension and wear.
- B. Fans:
1. Pre-Starting:
- a. Check the specified data and the shop drawing data against the installed data including:
 - (1) Make/model/size
 - (2) Fan wheel size
 - (3) Nameplate airflow, static pressure
 - (4) Motor size, speed, and efficiency
 - (5) Backdraft dampers
 - (6) Accessories
 - (7) Special features
 - b. Lubricate bearings on fans as per manufacturer's recommendations. Ensure wheels rotate freely without binding.
 - c. Ensure ductwork and fan casing is free of dirt or foreign material.
 - d. Ensure electrical connections are properly made and fan disconnects are properly located.
 - e. Ensure inlet and discharge duct geometry is properly installed.
2. Starting:
- a. Follow manufacturer's recommendations.
 - b. Check fan and motor for correct rotation.
3. Post-Starting:
- a. Check isolation and flexible connections.
 - b. Check radiated and discharge sound power levels.
 - c. Determine speed, airflow rates, static pressure and record on fan curve.
 - d. Pre-Interim Acceptance:
 - (1) Re-lubricate all bearings.
 - (2) Perform measurements of discharge, inlet and radiated sound power levels after entire system is balanced and adjusted.
- C. VAV Terminal Units:
1. Pre-Starting:
- a. Compare specified and shop drawing data to installed data including the following:
 - (1) Make/model/size

- (2) Maximum airflow (cfm)
- (3) Minimum airflow (cfm)
- (4) Direct or reverse acting controls

b. Check the following:

- (1) Inlet duct connection:
 - (a) Must have 4 duct diameters to box inlet.
 - (b) Must not have more than 12 inches flexible duct.
 - (c) Must not have flow straightening vanes.
- (2) Access to controls
- (3) Completeness of control documents
- (4) Silencer/acoustic duct
- (5) Exterior casing or controls are not damaged
- (6) Support

2. Starting:

a. Follow manufacturer's starting procedures.

3. Post-Starting:

- a. Measure airflow and inlet static at full flow.
- b. Set maximum airflows.
- c. Set minimum airflows.
- d. Determine minimum static pressure necessary to provide design airflow.
- e. Measure radiated sound power levels at 2 inches inlet static.
- f. Measure discharge sound power levels at 10 feet downstream.
- g. Check damper stroke over full range, minimum to maximum.
- h. Measure inlet air temperature.

4. Pre-Interim Acceptance: Not applicable.

D. Miscellaneous Air Handling Devices:

1. Motorized Dampers:

a. Compare specified and shop drawing data to installed data including:

- (1) Make/model
- (2) Size – minimum, maximum
- (3) Operator

b. Review the installation to ensure:

- (1) No cracks around damper frame
- (2) Blades close and seals engage completely
- (3) Damper strokes fully open to fully closed
- (4) Suitable access and identification

2. Gravity/Barometric Dampers:

a. Compare specified and shop drawing data to installed data including:

- (1) Make/model
- (2) Size

- (3) Throat and hood size
 - (4) Blade construction
 - (5) Blade seals
 - b. Review the installations to ensure:
 - (1) Damper fully closes – adjust weights
 - (2) No cracks or air leakage around frame
- 3. Air Outlets:
 - a. Compare specified and shop drawing data; to installed data including:
 - (1) Make/model
 - (2) Throat size
 - (3) Accessories
 - (4) Construction
 - b. Review the installation to ensure:
 - (1) Air outlet is clean.
 - (2) Air outlet is centered in space within the constraints of room layout.
 - c. Balance air outlet to specified value.
 - d. Take acoustical measurement on each outlet at specified airflows and compare to published data.
- 4. Fire Dampers:
 - a. Review the installations to ensure:
 - (1) UL label is visible.
 - (2) Track is clean of construction debris and dirt.
 - (3) Access for re-setting linkages.
 - (4) Installation is level.
 - (5) Blades are out of air stream.
 - (6) Temperature rating of fusible links.
 - (7) Check installation including wall angles, clearance between sleeve and wall (3/8-inch).
 - b. Test each fire damper to ensure that the blades fall smoothly and do not bind. Replace linkages.
- 5. Balancing Dampers:
 - a. Check installation to ensure:
 - (1) Damper can open and close fully.
 - (2) Access is clearly marked.
 - (3) Damper is not located in a turbulent air stream.

3.03 MISCELLANEOUS EQUIPMENT

A. Variable Speed Drive Units:

- 1. These starting procedures shall only be performed by qualified and factory trained technicians.

2. Visually inspect for the following items prior to commencing manufacturer's recommended starting procedures:
 - a. Voltage of unit and motor are same.
 - b. Transformer is properly installed.
 - c. Unit has UL labels.

B. Tanks:

1. Pre-Starting:
 - a. Check the specified and shop drawing data against the installed data including:
 - (1) Make/model/size/volume
 - (2) Pressure rating
 - (3) Labels ASME
 - b. Visually inspect to ensure no damage to:
 - (1) Access ports/manholes
 - (2) Piping sizes – inlet/outlet are correct
 - (3) Lining is intact and not damaged
 - (4) Piping is accessible to tank removal
 - c. Ensure adequate access to manholes.
2. Starting: Not applicable.
3. Post-Starting:
 - a. Verify operation of:
 - (1) Drain line
 - (2) Make-up line if applicable
 - (3) Gauge glass
 - (4) Diaphragm if applicable
4. Pre-Interim Acceptable: Not applicable.

C. Chilled Water Computer Room Air Conditioning Units:

1. Pre-Starting:
 - a. Compare specified and shop drawing data to installed data including:
 - (1) Make/model/size
 - (2) Electrical characteristics
 - (3) Cooling output
 - (4) Accessories: temperature controller, filters, leak detection, condensate pump
 - (5) Chilled water flow
 - (6) Airflow, external static pressure
 - (7) Discharge air temperature: dry bulb/wet bulb
 - (8) Entering air temperature: dry bulb/wet bulb
 - b. After installation, check the following:
 - (1) Drain pan and drain line installed correctly.

- (2) Unit is level and seismically restrained.
- (3) Internal isolators installed.
- (4) Chilled water complete.
- (5) Bearings greased.
- (6) Filters installed and are clean.

2. Starting:

- a. Start unit as per manufacturer's recommendations.
- b. Fill out manufacturer's check sheets.
- c. Post-Starting:

- (1) Verify the following:

- (a) Airflow
- (b) Static pressure
- (c) Entering dry bulb/wet bulb
- (d) Leaving dry bulb/wet bulb
- (e) Entering water temperature
- (f) Leaving water temperature
- (g) Water flow rates
- (h) Perform acoustical measurements.

- d. Pre-Interim Acceptance:

- (1) Change filters.

END OF SECTION

SECTION 23 08 21

MECHANICAL SYSTEMS STARTING AND TESTING

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. Check, start and test each system, verify that each system is operational and will operate to meet the specified operating criteria.

1.02 RELATED DOCUMENTS

- A. Section 23 05 01 - Mechanical General Provisions
- B. Section 23 05 93 - Mechanical Systems Balancing
- C. Section 23 08 01 - General Mechanical Starting and Testing Requirements
- D. Section 23 08 11 - Mechanical Equipment Starting and Testing

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

3.01 HYDRONIC SYSTEM

- A. Ensure piping in system is completed prior to performing cleaning, testing and starting operations.
- B. Ensure all valves are accessible.
- C. Ensure all major pieces of equipment are serviceable and complete with unions, isolating valves, etc.
- D. Test piping as follows:
 - 1. Cooling water – 1.5 times maximum working pressure or 150 pounds per square inch.
- E. During system full operational tests, check and document linear expansion at elbows, U-bends, expansion joints and offsets to ensure adequate clearance.
- F. Provide detailed written report defining outline of the entire proposed chemical cleaning procedure at least two weeks prior to cleaning including times, system status, problems encountered and the condition of the water. Procedure shall be approved by Architect prior to commencement of cleaning process.
- G. Perform a complete water analysis of all water being used prior to commencing operation. Include copy in report defined in 3.01.F. above. Ensure water being used will not damage systems being tested.
- H. Use water meter and record to $\pm\frac{1}{2}$ percent the volume of water in each system for each fill

cycle. The cleaning solution for chilled water systems shall be the following mass of chemicals per 400 gallons of water in the system:

| | |
|-----------------------|-------------|
| Tri Sodium Phosphate | 1 pound |
| Sodium Carbonate | 1 pound |
| Low Foaming Detergent | 0.02 pounds |

- I. Ensure system is free from construction debris, dirt and other foreign material.
- J. Remove, inspect and replace strainers on all systems prior to initial fill. Provide temporary strainers on pumps that do not have permanent strainers. Provide pressure circulating gauges on the strainers to detect plugging. Remove, clean and replace the strainers after the cleaning process is complete.
- K. Ensure all control valves are operational and fully open to ensure terminal units can be properly cleaned.
- L. System pumps may be used for cleaning provided a new set of seals is installed and pumps are dismantled and inspected. Replace worn parts, install new gaskets and turn over used seals.
- M. The system shall be completely operational, all safety devices functional and any hydraulic tests completed before cleaning.
- N. Add chemical solution to system. For steam boilers fill boilers only with cleaner.
- O. For water or glycol systems, establish circulation and apply heat to raise temperature slowly to maximum design temperature of system or 180 degrees F minimum. Circulate for 12 hours and ensure flow in all circuits. Remove heat and continue to circulate while the temperature is 100 degrees F or less. Drain system as quickly as possible. Refill with clean water; circulate for 6 hours at design temperature. Drain and repeat procedures defined above. Refill with clean water and add sodium sulfite. Test for residual sulfite.
- P. For chilled water or glycol systems circulate cleaning solution for 24 hours at maximum velocity at ambient temperature ensuring flow in all circuits. Drain as quickly as possible. Refill with clean water; circulate for 24 hours, drain. Refill with clean water and add sodium sulfite. Test for residual sulfite.
- Q. For steam systems fill to normal operating level with cleaning solution. Apply heat slowly and raise steam pressure to normal operating pressure. Hold pressure for four hours. Remove heat and allow to sit for 15 minutes. Blow out all boiler connections for 5-10 seconds. Refill boiler with clean water, apply heat and raise pressure. Hold pressure for one hour, remove heat, settle for 15 minutes, blow out all connections, refill. Repeat this 75-minute procedure three times. Allow boiler to cool, drain, open inspection ports and wash out with clean water. If boiler is not to be used immediately, refill with softened water, add sodium sulfite, bring up to pressure. Test for residual sulfite.
- R. For cooling tower systems, fill with clean water; circulate for one hour minimum at maximum flow. Drain and clean basin and screens. Refill, add chemicals and circulate. Test for residual chemicals.
- S. When cleaning is completed and system filled, establish circulation, expansion tank level and set pressure control.
- T. For steam systems, drain steam condensate until it is clean and free of suspended matter.
- U. On glycol systems, flush entire system with clean water before adding glycol solution. Test and establish circulating and pressure control. Test that the solution is freeze-proof to 0 degrees F. Use only pre-mixed glycol specified in Section 22 21 01 - Hydronic System

Specialties.

- V. Check to ensure all insulation is properly installed. Do not proceed with installation until all tests are completed to the satisfaction of the Architect.
- W. Submit with report certificate of compliance with specifications of cleaning component supplier.
- X. For heating systems perform the following tests:
 - 1. Check pressure bypass operation.
 - 2. Record system pressures, system temperatures, and system fluctuations by simulating maximum and minimum design conditions and varying:
 - a. Pump operation (e.g., P-1, P-2, P-1 and P-2)
 - b. Boiler operation
 - c. Pressure bypass open/closed
 - d. Control pressure failure
 - e. Maximum heating demand
 - f. Maximum cooling demand
 - g. Boiler failure (in multiple boiler systems)
 - h. Outdoor reset. Re-check heat exchangers output at 100 percent reset, 50 percent reset, maximum water temperature.
 - i. Flow failure
 - 3. Verify expansion tank levels from cold (60 degrees F) water temperature to maximum (210 degrees F) operating temperature.
 - 4. Check make-up operation on system by simulating blowdown and leak, and adjust PRV on water make-up. Ensure backflow preventer is installed and properly working.
 - 5. Record pressure drops across control valves.
 - 6. Set 3-way valves as per manufacturer's data.
 - 7. Check for sequencing of multiple boiler operations:
 - a. B-1 off
 - b. B-1 low
 - c. B-1 high
 - d. B-2 off
 - e. B-2 low
 - f. B-2 high
 - 8. Perform static pressure measurements and products of combustion analysis of boiler space to determine carbon monoxide, carbon dioxide and oxygen levels in room with:
 - a. All gas fired appliances firing full
 - b. No gas fired appliances firing
 - 9. Check high points in piping system for flow.
 - 10. Check for water noise.

3.02 DOMESTIC WATER SYSTEM

- A. Ensure piping in system is completed prior to performing flushing, testing and starting operations.
- B. Ensure booster pumps are properly started. Ensure all air chambers and expansion compensators are properly installed.

- C. Test to 150 pounds per square inch water pressure measured at system low point.
- D. Flush entire system for eight hours. Ensure full two hours of flushing through each outlet. Let stand for 24 hours and draw one sample off longest run. Submit to testing laboratory to verify system is clean. Let system flush for two more hours and draw off sample for testing.
- E. Shock treat entire system with liquid sodium hypochlorite to 5 percent concentration at end of line. Hold for 24 hours and flush systems for additional one hour.

OR

F. Disinfect water or piping as follows:

- ~~1. Chlorinate water mains in accordance with AWWA C601— Standard for Disinfecting water mains using calcium hypochlorite (H.T.H. 70).~~
- ~~2. Attach H.T.H. tablets to the top inside of each piece of pipe using white waterproof glue.~~
- ~~3. Number of tablets per 12 feet of pipe shall be:

 - ~~a. 6-inch diameter pipe: 1~~
 - ~~b. 8-inch diameter pipe: 2~~
 - ~~c. 10-inch diameter pipe: 3~~
 - ~~d. 12-inch diameter pipe: 5~~
 - ~~e. 14-inch diameter pipe: 6~~~~
- ~~4. In larger sizes of pipe, provide H.T.H. in sufficient quantities to dose the water with 50 ppm of chlorine for 12 hours.~~
- ~~5. After 12 hours the chlorine residual shall be more than 20 parts per million.~~
- ~~6. Flush water mains and safely discharge the water so that no downstream damage occurs.~~
- ~~7. Disinfection may be carried out simultaneously with testing provided the provisions of AWWA C601 are followed.~~
- ~~8. If repairs are made on any section of pipe, disinfection shall be repeated.~~
- ~~9. Tests for chlorine residuals and bacteriological samples and tests will be witnessed by the Architect.~~
- ~~10. Ensure entire system can be completely drained.~~
- ~~11. Check for proper operation of water hammer arrestors. Let one outlet run for ten seconds, then shut water off immediately. If water hammer occurs, replace water hammer arrestor or recharge air chambers. Repeat for each outlet and flush valve.~~

3.03 DUCTED SYSTEMS

- A. Power vacuum all ducts 36 inches and larger.
- B. Ensure exhaust, supply and return fans are all operational, and proper starting procedures completed and executed as defined in Section 23 08 11.
- C. Blow air through ductwork at 2 inches water gauge above system operating pressures to clean ducts and air outlets. Use system balancing dampers to assist in creating sufficient velocities.
- D. Test ductwork as follows:
 1. Low pressure – test for tightness such that leakage is inaudible and not detectable by feel.
 2. Medium and high pressure – test for tightness as specified by SMACNA manuals with maximum leakage of ½ percent at any branch or main duct at design static pressure. Ensure system is free of audible leaks.
 3. High pressure fume extraction – test for leakage of 0 percent at 3 inches water gauge static pressure on discharge side of fans and ½ percent leakage at 3 inches water gauge on suction side of fan.

4. Dust extraction – test for maximum leakage at ½ percent at 3 inches water gauge static pressure.
5. Kitchen exhaust ducts – test as defined in NFPA 96.
6. Low-pressure fume extraction – test for leakage of ½ percent at 3 inches water gauge on suction side of fan and 0 percent leakage at 3 inches water gauge on discharge side of fan.

3.04 PLUMBING DRAINAGE SYSTEMS (Sanitary, Chemical Waste and Storm)

- A. Test by filling with water to produce water pressure of 5 pounds per square inch minimum and 10 pounds per square inch maximum.
- B. For buried systems perform all tests prior to backfilling. Retest for proper grade and obstruction with hydraulic test.
- C. Ensure all traps are fully primed.
- D. Ensure all fixtures are properly anchored and connected to the system.
- E. Flush each valve, drain each sink and operate each fixture to ensure drainage.
- F. Open each cleanout, cover with linseed oil and reseal each cleanout. Ensure each cleanout is fully accessible and access doors are properly installed.
- G. Ensure roof drain metal domes are installed. Ensure storm piping is free of debris or roof insulation ballast. Remove caps as required. Verify insulation on piping as defined in Section 23 07 00 - Insulation.

~~H. In addition to pressure tests on chemical waste piping, check the following:~~

- ~~1. Chemical dilution [pit] [tank] installation.~~
- ~~2. Manhole at street.~~
- ~~3. Bottle traps properly installed and accessible.~~

- H. In addition to pressure tests check the following on kitchen waste systems:
 1. Piping is installed to withstand 180 degrees F discharge from dishwashers, boiler blowdown, etc.
 2. Grease trap accessible and properly installed.
- I. Verify that piping below mechanical boiler room is heat resistant.

3.05 STANDPIPE AND SPRINKLER SYSTEM

- A. Ensure installation of piping system is completed prior to performing starting and testing procedures. Ensure all equipment used has UL labels visible.
- B. Fill system with water. Record pressure of water supply.
- C. Pressure test piping system as per requirements of authorities having jurisdiction.
- D. Start fire pumps and jockey pumps as per Section 23 08 11.
- E. Ensure all valves in the sprinkler system are monitored and are clearly visible.
- F. Ensure all flow switches are installed and are operational.
- G. Flush systems as follows:

1. Filled with water, let stand at full operating pressure for one week. Drain each riser separately, then drain main.
 2. Repeat above procedure three times.
- H. Flow tests shall be performed as required by:
1. Authorities having jurisdiction
 2. NFPA 13
 3. San Francisco Codes
 4. NFPA 14
 5. NFPA 20
- I. Record incoming water pressure to building once a day for ten days prior to activating system.
- J. Adjust PRV on pump discharge to achieve maximum pressure of 90 pounds per square inch at top hose station. Adjust PRVs at lower hose stations to 80 pounds per square inch maximum.
- K. Test and place sprinkler valve into operation. Adjust pressure switches.
- L. Coordinate sequencing of fire alarm with Division 26.
- M. Record flow and pressure for fire pump and jockey pumps and inlet water pressure.

3.06 FIRE PROTECTION INERT GAS SYSTEMS

- A. Pressure test piping to 0 percent leakage at 125 pounds per square inch for a period of 24 hours.
- B. Ensure system is complete and installed as per the shop drawings.
- C. Ensure all penetrations into protected areas are caulked, weatherstripped or sealed with smoke dampers.
- D. Test each component to demonstrate it is functioning as per design intent. Operate each detector individually so as not to cause an alarm. Ensure panels annunciate as required.
- E. Check each alarm sounding device for audibility under normal operation.
- F. Check each interlock for proper operation as follows:
 1. Dampers close
 2. Doors close
 3. Equipment shuts off
 4. Pre-action sprinkler alarm activates
- G. Perform all of the above prior to actual discharge test.
- H. Test system using **[Inergen] [FM 200]** to the satisfaction of the Architect.
- I. Recharge system and leave in a fully operating mode.

3.07 MISCELLANEOUS SYSTEMS

- A. Test the following systems as follows:
 1. Refrigerant piping: Test with nitrogen to 300 pounds per square inch on high

- pressure side and 150 pounds per square inch on low pressure side.
2. Compressed air: Test piping to 150 pounds per square inch pressure with nitrogen. Maintain pressure for 24 hours with maximum 1.5 pounds per square inch pressure drop.
 3. Vacuum: Test piping to 150 pounds per square inch pressure with nitrogen. Maintain pressure for 24 hours with maximum 1.5 pounds per square inch pressure drop.
 4. Medical gas: Test as described in NFPA 99 – Medical Gas Piping.
 5. Gas piping: Test as required by authorities having jurisdiction.
 6. Control air piping: Test to maintain air pressure at a maximum 1 pound per square inch pressure drop.
 - a. Mains – test to 150 pounds per square inch.
 - b. Branches – test to 100 pounds per square inch.

3.08 TESTING OF SPECIAL DUCT SYSTEMS

- A. An independent testing laboratory whose equipment, facilities and qualifications are acceptable to the Architect shall perform tests.
- B. Perform 100 percent ultrasonic testing inspection on all welded special fume exhaust systems on the discharge side of the fan.
- C. Welded ductwork shall be subjected to leakage tests at 3 inch water gauge static pressure with 0 percent leakage over 8 hours.
- D. Cut out and replace one welded fitting for testing.
- E. Selection of fittings shall be by the Architect.
- F. Delivery to testing facility shall be by the Architect.
- G. Replace all fittings found to be defective by above tests.

3.09 TESTING OF SOLDERED PIPE FITTINGS FOR SYSTEMS CONVEYING MEDIA OVER 60 DEGREES F

- A. Prior to commencement of work, each tradesman involved shall solder two joints in the presence of the Architect and immediately turn over to the Architect, properly identified with date, name of solderer, project, to serve as reference samples.
- B. Prior to starting system a sample of ten joints (½ percent of total joints on project) shall be cut out and immediately turned over to the Architect for conveyance to approved independent testing laboratory to determine that the 95-5 solder meets ASTM B32 Grade S65 standards.
- C. Prior to starting system, perform X-radiography inspection by an independent testing agency on twenty joints. Each joint shall be subjected to two separate X-rays taken normal to the pipe axis and angles 90 degrees apart and subjected to the following analysis (gamma rays or sonic inspection shall not be considered acceptable):
 1. Pipe penetration into base of socket (must be 95 percent or better penetration).
 2. Void Path Length (VPL) and Combined Void Path Length (CVPL) shall not exceed 50 percent of mean length of joint.
 3. If a void is closer to the edge of the joint than 10 percent of mean joint length the axial VPL and CVPL through that point shall not exceed 40 percent of the mean length of the joint.
 4. Circumferential VPL and CVPL shall not exceed 50 percent of joint circumference. Circumferential measurements shall only be made within the center 70 percent of the pipe cross section projected on the radiograph.

5. No single void shall have a circumferential VPL or CVPL exceeding 25 percent of joint circumference. Total void area shall not exceed 25 percent of total joint area.
- D. All joints shall meet criteria above. If two or more joints fail this test, repeat with a 4 times larger sample. If any of these joints fail, replace all joints on site.
- E. Joint selection shall be made by random by the Architect.
- F. Conveyance to testing facility shall be by the Architect.

3.10 CONTROLS

A. General:

1. Provide complete system documentation before start of testing:
 - a. System manuals including hardware, software, maintenance and operations
 - b. Interlock and control diagrams for all systems controlled
 - c. Shop drawings and calibration procedures
 - d. Written description of control strategy for each system
 - e. Table of operating setpoints and alarm limits for control strategies
 - f. Listing of actual data file for each point and for control strategies
 - g. Certification of operation and list of calibration requirements of all hardware components

B. Hardware Starting:

1. Ensure each hardware component is properly installed as per manufacturer's recommendations and functioning properly.
2. Hardware setting:
 - a. This testing must be completed and verified before any software logic and control is added to the system.
 - b. Calibrate the following components as per manufacturer's recommendations:
 - (1) Thermostats and temperature sensors
 - (2) Damper motor operators and positioners
 - (3) Valves operators and positioners
 - (4) Transmitters
 - (5) Humidistats and humidity sensors
 - (6) Air compressors, dryers
 - (7) Pressure reducing/relief valves
 - (8) Clocks
 - (9) Gauges, thermometers, etc.
 - (10) Pressure/electric switches
 - (11) Static sensors and transmitters
 - (12) Flow switches
 - (13) Carbon monoxide sensors and alarm points
 - (14) Alarm settings
 - (15) Fire alarm and security system interface
 - (16) Interposing relays
 - (17) Current sensitive relays
 - c. Pressure test all pneumatic air tubing as per Section 23 08 11.
 - d. Gauge all wiring used to ensure conformance to UL specifications. Ensure all circuits are complete and all terminal wiring connections are tight.
 - e. Adjust control dampers. Ensure uniform mixing. Ensure tight shut-off closure and measure leakage. Configure for fail-safe operation.

- f. Put control compressor and air dryer into operation. Ensure oil levels are full; moisture blowdown is operational; air filter is clean. Adjust PRVs.
- g. Put all electronic hardware into operation in accordance with manufacturer's recommendations. Replace all defective components. Prove proper operation with software starting and printout.
- h. Test and ensure all interface with Division 26 is complete. Test and ensure all interface with other "package control" is complete.
- i. Ensure point identification is completed and all wire labeling is completed. As a minimum standard, the point tag should contain the following information:
 - (1) Logical point name
 - (2) Point multiplexer
 - (3) Address
 - (4) Associated system identification
 - (5) Point description
- j. If dynamic graphics are included, ensure the proper operation of:
 - (1) Dynamic values displayed on screen
 - (2) Update period
 - (3) Color change or status change
 - (4) Proper identification of system and points on screen
 - (5) Reaction to alarms
- k. Check out each point through the terminal device end-to-end. This checkout to include tests for range, reliability and repeatability.
- l. Calibrate all control valves:
 - (1) Ensure no overlap of control ranges.
 - (2) No leakage when valves are closed, particularly steam.
 - (3) Failsafe operation
- m. Check all interface cabinetry to ensure compliance with the specifications and applicable codes.

C. Software Starting:

- 1. Ensure all hardware is completely installed and started and fully operational before software start-up.
- 2. Compare shop drawings and specifications to final software and check:
 - a. Flow charts
 - b. Hardcopy printouts
 - c. Control flow logic diagrams
- 3. Enter software and operating setpoints and schedules into terminal device.
- 4. Check out each system through the terminal by:
 - a. Simulation of system start/stop functions.
 - b. Simulation of systems operation including:
 - (1) High limit functions
 - (2) Low limit functions
 - (3) Safety features (override values)
 - (4) Operation sequences specified
 - c. Verification of system component hardwired interlocks.

5. Verify operation of specific routines such as:
 - a. Optimization
 - b. Demand limiting
 - c. Peak shaving
 - d. Night setback, morning warm-up
 - e. Building dynamic control
 - f. Variable volume air systems supply/return fan tracking control
 - g. Power failure recovery
6. Simulate alarm conditions and verify alarm printouts.
7. Check out reports generation.
8. Check out communication network, input and output.
9. Check operation of system under failure modes:
 - a. Component failure
 - b. Smart remote failure
 - c. Communication failure
 - d. Host failure
 - e. Outside air sensor failure

END OF SECTION

SYSTEM COMMISSIONING

PART 1 – GENERAL

1.01 DESCRIPTION

- A. Provide commissioning for all water and air systems in accordance with the Contract Documents.
- B. The commissioning must be carried out by a Commissioning Specialist. The Commissioning Specialist shall be an individual, team or company appointed to undertake the commissioning of the installed services systems in accordance with this specification.
- C. The commissioning shall be supervised by Commissioning Management Consultant appointed by the employer responsible for the overall planning, supervision and witnessing of the results of the integrated commissioning of all installed building services systems and their associated plant and equipment.

1.02 WORK INCLUDED

- A. Preliminary and final adjustment of water systems.
- B. Preliminary and final adjustment of air systems.
- C. Temporary pipe and duct connections, pipe caps, duct caps, tees, valves, dampers, etc.
- D. Performance testing of ACMV systems.

1.03 CODES OF PRACTICE

- A. All commissioning works covered by this specification shall be carried out strictly in accordance with the particular specification and the latest ACG Commissioning Guidelines and ASHRAE Guideline 1-1996. Furthermore, where requirements set forth in the particular specification differ from the above standards then the contract requirements shall prevail.
- B. Where there is any element of doubt as to the interpretation of the scope of work and phrases used in this specification the Commissioning Specialist shall apply for clarification at the time of his tender. Where no application is made, it is deemed the Commissioning Specialist has fully interpreted the intentions of the contract documents.

1.04 SUBMITTALS

- A. Provide the following to the Owner at least six months prior to the anticipated commencement of commissioning activities on site:
 - 1. A copy of the Specialist's current ACG Registration Certificate, where appropriate.
 - 2. A profile of the Specialist's organization giving details of staff and project experience.

3. A copy of the Specialist's Safety Policy and the name of his Project Safety Representative.
4. Details of the qualifications and experience of all senior staff proposed for the project including copies of their individual ACG Registration Certificates (where applicable).
5. Identification of the Specialist's nominated lead engineer.
6. A particular method statement detailing the standard pre-commissioning checks (where appropriate) and the commissioning, recording, documentation and reporting procedures to be adopted by the Specialist including samples of all proposed test and record sheets.
7. Where requested by the employer, written procedures to be undertaken by the specialist's personnel in commissioning of the installed systems.
8. Information on the scheduled duration of the commissioning activities to be undertaken by the Specialist on each of the relevant systems including details of any special pre-requisites or system interdependencies in order that an integrated project commissioning programme may be produced by the project manager.
9. A full set of the ductwork shop drawings marked up with the location of each range of test holes required by the Commissioning Specialist including information on the size and spacing of these test holes. The proximity of adjacent services should be considered by the installer when positioning test holes and final locations shall be agreed on site in congested areas.
10. A formal preliminary report by the Commissioning Specialist following his review of the information supplied by the Employer highlighting any deficiencies noted on the drawings or any apparent discrepancies and/or omissions in the design data submitted. The Specialist shall pay particular attention here to key items such as damper locations and the size and location of installed water flow measuring/regulation devices.

1.05 DOCUMENTATION

- A. The Commissioning Specialist shall record the results of his works on standard test and check sheets. These may be his in-house standard sheets of pro-forma developed specifically for the project. In either case, the sheets should comply with the recommendations given in ACG guidelines.
- B. The Commissioning Specialist shall also be responsible for preparing and submitting a preliminary report see interim reports, progress reports and a final report.

1.06 SCOPE OF WORKS

- A. Unless otherwise indicated, the Commissioning specialist shall be responsible for all aspects of Pre-Commissioning, Commissioning Recording and Demonstration of results for witnessing of mechanical engineering services and provision of instrumentation and all things necessary for these works.
- B. The Commissioning Specialist shall carry out all pre-commissioning checking, plant start-up, initial running checks, fluid flow regulation and systems and equipment performance testing of all of the mechanical services systems shown on the accompanying drawings (listed hereunder) and as required. Where certain of the systems fall outside of the

scope of works then the systems actually included are those listed below . All of this work shall be carried out strictly in accordance with the specification.

- C. The Commissioning Specialist shall carry out the initial running checks, flow regulation and systems and equipment performance testing of all of the mechanical services systems shown on the accompanying drawings and as required by this specification. Where certain of the systems detailed in this specification fall outside of this scope of works then the systems actually included are those listed below. When pre-commissioning checks and plant start-up have been carried out by others, the Commissioning Specialist shall satisfy himself that the aforementioned checks have been carried out fully in accordance with the particular specification and that operational safety is maintained for all systems. All of this work shall be carried out strictly in accordance with this specification.
- D. The Commissioning Specialist shall carry out the pre-commissioning and initial running checks of all fans and pumps associated with the included systems. The commissioning of all other major plant items such as chillers and controls will be carried out by the respective Manufacturers' Commissioning Engineers. The Commissioning Specialist shall provide such attendance as is required to the Manufacturers' Commissioning Engineers. The Commissioning Specialist shall provide such attendance as is required to the Manufacturers' Commissioning Engineers to regulate and prove fluid flow rates and to operate the associated systems.
- E. The Commissioning Specialist shall provide all skilled labor, instruments and tools required in order to carry out his works, fully in accordance with this specification the particular specification and the contract requirements.
- F. The work shall include the provision of reports both interim and final.

1.07 ATTENDANCE

- A. The Commissioning Specialist will require the attendance of others at certain stages of the commissioning process and the Employer will arrange for this attendance to be available as and when required. The Specialist shall give due notice to the Employer of his attendance requirements, prior to commencement in order that this may be incorporated into the commissioning programme.
- B. The attendance will include, but not necessarily be limited to the following:
- C. The attendance of the Controls Commissioning Specialist during initial plant start-up to verify the correct functioning and calibration of motor starters and safety systems. The Controls Commissioning Specialist should also be available to manipulate motorized dampers and control valves in preparation for system balancing, particularly on software driven systems.
- D. The attendance of certain Manufacturers' Commissioning Engineers during the start-up and initial running of large or sophisticated fan or pump assemblies.
- E. In addition to the above attendance furnish personnel to be available at short notice during the pre-commissioning and initial run stages, and to a lesser extent throughout the commissioning process, in order to respond rapidly to contingencies as these may come to light.

1.08 SYSTEMS COMPLETION

- A. The Commissioning Specialist shall commence his works on completed systems in accordance with the agreed commissioning programme. No work shall be undertaken by

the Commissioning Specialist on incomplete systems unless he is in receipt of a formal instruction to do so from the Employer.

- B. The Commissioning Specialist shall issue copies of a standard Systems Completion Certificate pro-forma to the Employer at the Submissions Stage.
- C. The Commissioning Manager will notify the Commissioning Specialist that a particular system or group of systems are complete and that the required attendance are available.

1.09 INSTRUMENTS

- A. All instruments brought to site by the Commissioning Specialist shall be in good working order. The Commissioning Specialist shall hold, on site, copies of the calibration certificates for all of the instruments in use on that site. Should any instrument become due for re-calibration during the commissioning process it shall be removed immediately from service and not re-used until a new calibration certificate is available.
- B. The Commissioning Specialist shall ensure that the following basic instruments are available on site, and in sufficient numbers, to comply with programmed activities as required.
 - 1. Clip-on Ammeter – for ac current measurements.
 - 2. Multimeter – for measurement of resistance and ac/dc voltage.
 - 3. Tachometer – mechanical and/or optical for shaft speed measurements.
 - 4. Electronic Direct Reading Anemometer for airflow measurements.
 - 5. Inclined Manometer and/or Micromanometer – for airflow and air pressure measurements together with pitot tubes of various lengths.
 - 6. Digital Electronic Thermometer – with immersion and contact probes.
 - 7. Sling Psychrometer and/or Electronic Hygrometer – for in-duct or space dry & wet bulb temperature and humidity measurements.
 - 8. Fluoro carbon filled Test Set with adaptors – for low-loss water pressure measurement.
 - 9. Mercury-filled Test Set with adaptors – calibrated for high-loss water pressure measurements.
 - 10. Pressure Gauges – for water pressure measurements.
 - 11. Mercury in glass thermometers – for checking digital electronic thermometers.
 - 12. Digital electronic water manometer.

1.10 DEFICIENCIES

- A. The Commissioning Specialist shall bring to the notice of the Employer, with the minimum of delay, all deficiencies in systems installation or equipment performance which come to light during the commissioning process by means of the interim reports.
- B. Such reports are also to include any deficiencies noted which may not necessarily have an impact on commissioning but could effect system performance and safety.

- C. Should the Commissioning Specialist consider that a discovered deficiency may result in damage to plant or systems or impair operational safety in any way, then he shall immediately shut down and lock off that plant. The plant shall not be restarted until formal clearance to resume work is issued by the project manager.

1.11 REPORTING

- A. The Commissioning Specialist shall submit written reports to the Owner at certain stages of the works as follows:
 - 1. A preliminary report relating to his review of the drawings and design data prior to commencement on site.
 - 2. Interim reports, as appropriate, detailing any deficiencies and performance shortfalls which may come to light as the commissioning works progress.
 - 3. Progress report, as and when required by the Employer, in order that progress against the agreed programme may be monitored.
 - 4. A final report on each completed system or group of systems incorporating the results documentation and a signed summary/acceptance sheet to be counter signed by the witnessing authority.

1.12 COMMISSIONING OF WATER SYSTEMS

- A. Water flow rate shall be measured and regulated by flow meter and/or identifying the pressure drop across measuring devices built into each of the paths while the water is circulated at ambient temperatures. Portable mercury filled manometers shall be employed for this purpose.
- B. Implement all preliminary checks, system flushing, setting to work, balancing and regulation in accordance with CIBSE Commissioning Code, Series W.

PART 2 – PRODUCTS

2.01 Not Used

PART 3 – EXECUTION

3.01 AIR DISTRIBUTION SYSTEMS

- A. Pre-commissioning Checks
 - 1. The Commissioning Specialist shall, on receipt of a Systems Installation Completion Certificate or other notification from the Owner, satisfy himself that the completion status of the system is sufficiently advanced for commissioning to commence safely.
 - 2. The installer will be responsible for ensuring that access to all damper handles access doors and test holes are not obstructed by insulation or other system or building elements.
 - 3. The Commissioning Specialist shall carry out static pre-commissioning checks generally in accordance with the particular specification.
 - 4. The Commissioning Specialist, in liaison with the Controls Commissioning Specialist, shall satisfy himself that all system safety devices are operational with

particular reference to frost protection devices and emergency stop/lock-off buttons and that access to rotating plant is restricted to authorised personnel.

5. The Commissioning Specialist, in liaison with the Controls Commissioning Specialist, shall ensure that all motorised dampers are in the fully open position and that they will remain fully open during commissioning. Where systems have facilities for re-circulation of return air then these shall be set to the full fresh air/full exhaust, position for start-up and balancing except in circumstances where frost damage may result.
6. The Commissioning Specialist, in liaison with the Controls Commissioning Specialist, shall ensure that, where practicable, measures are taken to enable the initial start-up of fans to be carried out under low load conditions.
7. Where variable speed fan drive facilities are incorporated these shall be checked in accordance with the manufacturer's instructions and set to minimum speed for initial start-up.

B. Plant Start-up and Initial Running

1. Following the satisfactory completion of the foregoing pre-commissioning checks, the Commissioning Specialist shall, in conjunction with the Controls Specialist, carry out fans start-up and initial running checks.
2. The Commissioning Specialist shall give notice of initial plant start-up to the Employer in order that suitable measures may be taken to protect building contents and finishes from dust discharge from system outlets.
3. Once initial running is complete and the Commissioning Specialist is satisfied with the operational safety of the system he shall carry out an initial appraisal of fan performance, with the system on maximum load, prior to the commencement of airflow regulation (balancing). This initial appraisal shall comprise the measurement and recording of the following:-
 - a. Fan Total Airflow – by means of a single main duct pitot traverse or the sum of traverses in the main branch ducts.
 - b. Fan Static Pressure
 - c. Fan and drive motor shaft speeds
 - d. Voltage and full running current of drive motor
 - e. Air temperature at the fan inlet
 - f. Pressure differential across each system filter assembly
4. Note The fan total volume under these conditions (filters clean and system unbalanced with all dampers open) should be appreciably above the design figure. If under these conditions the total volume is at or below the design level then the Commissioning Specialist, having rechecked the systems to ensure that no obstructions have been overlooked, shall report his initial findings to the Employer in order that further investigations may be carried out in conjunction with the fan manufacturer and the Engineer. In the event that the total airflow is less than 80% of design then airflow regulation shall not be commenced until all-party discussions have taken place and a strategy has been agreed formally.

5. The Commissioning Specialist shall ensure that the running current of any drive motor does not exceed the full load current quoted on the equipment nameplate for a prolonged period at any state of the commissioning process.

C. System Airflow Regulation

1. The Commissioning Specialist shall consider the state of advancement of building finishes prior to the commencement of balancing. For air distribution systems serving areas where doors etc have not been fitted the commissioning specialist shall only commence commissioning under written instruction from the employer.
2. The Commissioning Specialist shall use, wherever practicable, a purpose made hood in conjunction with a direct reading electronic anemometer when carrying out the balancing of air terminals.
3. Should the Commissioning Specialist in the course of balancing, find an unusually low flow rate at a terminal or branch he shall recheck the ductwork in that area for obstruction or leakage before continuing to regulate flow rates. Any problems with unresponsive or noisy branches noted during balancing shall be immediately brought to the attention of the Owner for discussion with the Engineer.
4. Balancing between branches shall always be carried out using the branch duct dampers. In general the dampers installed in terminal grilles and diffusers shall only be used or the local balancing between the terminals on a particular branch.
5. Note On the completion of the balancing exercise at least one terminal or any dampened sub-branch should be fully open as should all dampers on the path from the fan to the true index terminal.
6. Main or branch dampers shall not be used to reduce overall fan airflow rates except on small, direct drive fans. If a system remains in excess of the specified design upper limit for airflow on completion of the balancing exercise then fan speed reduction by pulley change or pitch adjustment shall be undertaken by the installer to bring the total airflow within tolerance.
7. On completion of a system balance a final set of airflow readings shall be taken and recorded on the agreed test sheet. Where complementary supply and return air systems normally operate together the final readings shall be taken with both systems operational and balanced. Duct damper settings shall be lightly marked at this stage prior to demonstration of results.
8. The Commissioning Specialist shall take total airflow measurements in the main duct or main branch ducts. These readings shall be taken using an inclined manometer or an electronic micromanometer in conjunction with a pitot tube of suitable length.
9. The Commissioning Specialist, in conjunction with the Controls Commissioning Specialist shall set up the design minimum fresh air quantity on systems with fresh air constant volume dampers.
10. When all of the foregoing checks and tests are satisfactorily completed and demonstrated, in accordance with this specification, the Controls Commissioning Specialist will normalise all distribution system and plant control sensors set points.

11. The Commissioning Specialist shall measure and/or record on the appropriate test sheet, the following data on each fan set on completion of system balancing: Indicate the design and actual operating condition:
 - a. Fan Total Airflow – ctm
 - b. Fan Static Pressure – inches of water
 - c. Fan Shaft Speed
 - d. Motor Shaft Speed
 - e. Motor Applied Voltage and full load Running Current
 - f. Motor Starter Fuse Rating, Overload Setting and Timer Setting (where applicable)
 - g. Fan Nameplate Data
 - h. Motor Nameplate Data
 - i. Drive Details

12. Balance and adjust supply air systems as follows:
 - a. Systems installed with trunk ducts only, with no air outlets, to be balanced by adding a volume damper at each end of the trunk duct (minimum of two (2) dampers per system if duct is looped). Make adjustments to the air handling units as required to deliver the volume of air within 10% of design flow at the static pressure and cold air supply temperature shown on the Drawings. Remove dampers and seal or re-cap openings after reports have been accepted by Engineer (All floors)
 - b. Systems installed with main duct capped at wall of fan room will be balanced by installing an opposed blade damper at each capped connection. Make adjustments as required to deliver the volume of air within 10% of design flow at the static pressure and cold air supply temperature shown on the Drawings. Remove dampers and re-cap openings after reports have been accepted by Engineer (3 typical floors)
 - c. Systems installed partially complete will be balanced by installing a volume damper in duct allocated for remaining portion of system. Make adjustments as required to deliver the volume of air within 10% of design flow at the static pressure and cold air supply temperature shown on the Drawings. Remove damper and re-cap or seal openings after reports have been accepted by the Engineer . (All floors)
 - d. Balance and adjust supply air systems installed in finished areas of the building (except for areas with inaccessible ceiling construction) as follows:
 - (1) After duct systems have been installed complete with all grilles, dampers, ducts, coils, automatic temperature controls, and other items hereinafter specified, make the adjustments to the air handling units and all outlets as required to deliver the volume of air within 5% of design flow as shown on the Drawings with design cold duct temperatures. After the finished area is

occupied, readjust the air volumes if required, to properly balance the cooling and heating loads throughout the conditioned areas.

- e. Balance and adjust completed supply air systems installed in areas with inaccessible ceilings as follows:
 - (1) After duct systems have been installed complete with all dampers, ducts, coils, and other items hereinafter specified, except for final connection to grille or air outlet, and prior to inaccessible ceiling installation, make adjustments, as required, to deliver the volume of air at each interior and perimeter air tap proportionally within 5% of design flow as shown on the Drawings.
 - (2) After each duct system has been adjusted, securely lock each manual damper, splitter, spin-in damper, etc., with sheetmetal screws prior to installation of ceiling.
 - (3) Submit balancing reports to the Engineer for review and comment as specified hereinafter, prior to the installation of the inaccessible ceiling. Do not conceal duct system prior to the receipt of an air balance report which has been accepted by the Employer for the system.
 - (4) After ceiling installation, install each air outlet with air patterns as shown on the Drawings. Make final air balance adjustment by increasing or decreasing the fan powered terminal unit fan rpm.

D. Air Handling Plant Performance Tests

- 1. The Commissioning Specialist shall measure and record the static pressure loss, at or near design airflow, of all installed cooling coils and attenuators.
- 2. The Commissioning Specialist shall carry out thermal performance tests on all installed cooling coils and record the results on the appropriate test sheets.
 - a. For cooling coils – measure and record entering and leaving wet and dry bulb temperatures and water flow and return temperature with:
 - (1) airflow rate at or near design entering air temperature and humidity stable and at or near design water flow rate at or near design and control valve fully open to coil water flow temperature stable and at design

E. Systems Incorporating VAV/CAV Airflow Controllers

- 1. Prior to initial plant start-up the Commissioning Specialist, in conjunction with the Controls Commissioning Specialist, shall configure the temperature controlled, VAV devices to full cooling – maximum airflow status. The precise method used to achieve this will vary dependent on the proprietary VAV units installed.
- 2. The Commissioning Specialist, in conjunction with the Controls Commissioning Specialist, shall carry out air handling plant start-up. Following start-up and initial running of the fans the system static pressure sensor control set point shall be gradually raised until either the design value is achieved or stable maximum working fan speed is reached. The Commissioning Specialist shall then take

preliminary static pressure readings immediately upstream of selected VAV units to ensure that pressure distribution throughout the system is satisfactory and that all VAV units are operating above their design minimum pressure (lift-off pressure) as specified by the manufacturer.

3. On systems where factory-calibrated VAV/CAV units are installed, the Commissioning Specialist shall proceed to carry out proportional balancing of groups of terminal supply grilles or diffusers downstream of each VAV/CAV unit previously set to full cooling – maximum airflow. On completion of this exercise at least one terminal damper in each group shall be fully open and under no circumstances shall attempts be made to reduce the aggregate airflow of a VAV/CAV unit using these terminal dampers.
4. The Commissioning Specialist, in conjunction with the Controls Commissioning Specialist, shall then progressively check the airflow calibration of each VAV/CAV unit where downstream balancing has already been carried out. The airflow rate shall be verified in turn on each unit in both the high (full cooling) and low (full heating minimum cooling) status by the manipulation of individual temperature set points (or other suitable means) and the results recorded. Each of the VAV units shall be reset to the full cooling mode once this calibration check is complete. The VAV/CAV unit airflows shall be determined using signals from in-built flow measuring grids where available or by means of a pitot traverse taken in the upstream high velocity duct. Upstream static pressure on each VAV/CAV unit shall also be measured and recorded as part of this calibration check.
5. All of the remaining VAV units that were set to full heating minimum cooling-minimum airflow status to simulate system diversity shall now be set to full cooling a corresponding number of already calibrated units sets to full heating minimum cooling minimum airflow. The Commissioning Specialist shall then proceed to carry out downstream proportional balancing and calibration checks of these remaining units.
6. Details of any defects or deficiencies in the calibration of VAV/CAV units which come to light during the calibration check shall be recorded and reported to the Employer. Where necessary, re-calibration of faulty units should be carried out by the Manufacturer's Commissioning Specialist or by the Commissioning Specialist if he is duly authorized and instructed to do so.
7. The Commissioning Specialist shall carry out proportional balancing of the associated return air systems and set up, in conjunction with the Controls Commissioning Specialist any return air zone control, motorized dampers.
8. The Commissioning Specialist shall carry out total airflow measurements and minimum fresh air adjustment and where required, air handling plant performance tests.
9. The Commissioning Specialist, in conjunction with the Controls Commissioning Specialist, shall check and adjust "tracking " of the return air fans. This shall be achieved by progressively reducing the total system supply air volume from design maximum to minimum (by manipulation of temperature set points) whilst simultaneously measuring the total supply and return air volumes to ensure that the fan volumes remain proportional and stable throughout the operating range. This exercise shall be repeated on an increasing supply airflow. This "tracking" exercise shall initially be carried out with the system in full fresh air mode. The system shall then be configured to the minimum fresh air mode and the above "tracking" exercise repeated with the additional simultaneous measurement of

the fresh air quantity to ensure that this remains constant and unaffected by system total airflow changes. The operation and “tracking” of individual return air zone modulating dampers, where fitted, shall also be verified in a like manner.

10. Once all of the foregoing checks and tests are satisfactorily completed and demonstrated, the Controls Commissioning Specialist shall normalize all distribution system and plant control sensor set points.

F. Witnessed Demonstrations

1. On completion of all of the foregoing on any system, or group of systems, the Commissioning Specialist shall finalize and collate the test sheets and submit a copy with a summary/witnessing sheet to the Employer.
2. The Commissioning Specialist shall demonstrate his documented figures to the witnessing team. Upon satisfactory completion of the demonstration a member of the witnessing team will counter sign the summary sheet confirming that the recorded results have been witnessed.
3. On receipt of confirmation that the balancing on a system has been accepted by the Engineer / the Commissioning Specialist shall indelibly remark all balancing damper positions and replugin test holes.

3.02 WATER DISTRIBUTION SYSTEMS

A. Pre-Commissioning Checks

1. The Installer will prepare the systems for commissioning – filling, flushing and venting all in accordance with this specification. Pre-commissioning Cleaning of Water Systems and ensure that clear access available to all test points and valve handles.
2. The Commissioning Specialist shall on receipt of a Systems Installation Completion Certificate or other notification from the Employer, satisfy himself that the completion status of the system is sufficiently advanced for commissioning to commence safely.
3. The Commissioning Specialist, in liaison with the Controls Specialist, shall carry out static pre-commissioning checks Mechanical and Electrical Checks, and in compliance with the standard pre-commissioning check list of this specification.
4. The Commissioning Specialist, in liaison with the Controls Commissioning Specialist, shall ensure that all motorized valves are in the fully open to load position and that they will remain fully open during commissioning. The Commissioning Specialist shall check that all system valves, isolating and regulating, are fully open. Should he find certain valves closed in the course of this check he shall notify the Installer and shall not attempt to open them himself.

B. Plant Start-up and Initial Running

1. Following the satisfactory completion of the foregoing preliminary checks the Commissioning Specialist shall, in conjunction with the Controls Specialist, carry out pump start-up and initial running checks.
2. Once initial running is complete and the Commissioning Specialist is satisfied with the operational safety of the system he shall carry out an initial appraisal of pump performance, with the system on maximum load, prior to the

commencement of water flow regulation (balancing). This initial appraisal shall comprise the measurement and recording of the following and in the case of dual pump sets shall be undertaken for both pumps.

- a. Total Fluid Flow Rate – using the main orifice plate or venturi.
 - b. Pump Differential Pressure – using a single, calibrated pressure gauge.
 - c. Closed Valve Pump Differential Pressure – using above gauge.
 - d. Pump and drive motor shaft speeds
 - e. Voltage and full load running current of pump motor.
 - f. Pressure differential across main system strainer assembly.
3. If the pump total fluid flow rate as measured and recorded above is at or below the design level then the Commissioning Specialist, having rechecked the systems to ensure that no valves have been overlooked, shall report his initial findings to the Employer in order that further investigations may be carried out in conjunction with the pump manufacturer and the Engineer. In the event that the total flow rate is less than 80% of design then balancing shall not be commenced until all-party discussions have taken place and a strategy has been agreed formally.
 4. Note The pump total flow rate under these conditions (strainers clean and system unbalanced with all valves open should be appreciably above the design figure.
 5. The Commissioning Specialist shall ensure that the running current of any drive motor does not exceed the full load current stated on the nameplate for a prolonged period of any stage of the commissioning process.
 6. The Commissioning Specialist shall run the pump set for a period of at least four hours monitoring the total flow rate and main strainer pressure differential at regular intervals. If during this initial run, a reduction in main flow and/or an increase in strainer pressure drop is noted (indicating that a level of dirt is still present in the system) then this shall be reported to the Employer/Systems Cleaning Specialist with a request for further action.

C. System Fluid Flow Regulation (Balancing)

1. When satisfied that the system fluid flow rate is stable the Commissioning Specialist shall carry out the proportional balancing of the system. The tolerances to be applied shall be those detailed in the particular commissioning specification.
2. The particular valve manufacturer's recommendations for the minimum permitted degree of opening of regulating valves shall be adhered to at all times.
3. Should the Commissioning Specialist, in the course of balancing, find an unusually low flow rate at a terminal or branch he shall check the manufacturers' pressure loss data for components on that branch before continuing with the balance. If problems with an unresponsive branch cannot be explained by unusually high resistance components he shall immediately report this findings to the Employer with a request for further investigation. Problems with particularly high resistance terminals or branches should be brought to the attention of the

Engineer by the Employer.

4. Note Regulating techniques to promote flow in a high resistance branch are likely to adversely influence overall system flow rates with little improvement to that individual branch and other solutions should be considered.
5. On completion of the system balancing the Commissioning Specialist shall measure and record a final set of water flow rates on the agreed test sheet. All system double regulating valve settings shall also be recorded and all test point caps shall be replaced.
6. The Commissioning Specialist shall measure and/or record on the appropriate test sheet – the following data on each pump on completion of the system balancing. Indicate the design requirements and the actual operating conditions.
 - a. Pump Total Fluid Flow – gpm
 - b. Pump Discharge Pressure – psig
 - c. Pump Suction Pressure – psig
 - d. Pump Impeller Diameter
 - e. Pump Shaft Speed
 - f. Motor Shaft Speed
 - g. Motor Applied Voltage and Running Current
 - h. Motor Starter Fuse Rating, Overload Setting and Time Setting (where applicable)
 - i. Pump Nameplate Data
 - j. Motor Nameplate Data
 - k. Drive Details

D. Pump and System Performance Tests

1. The Commissioning Specialist shall measure and record dynamic pressure losses through all the following system components where provided with suitable pressure tapings:
 - a. Cooling Coils
 - b. Plate Heat Exchangers
 - c. Control Valves
 - d. Systems strainers (clean)
 - e. Chiller evaporators and condensers.
2. The Commissioning Specialist shall measure and record dynamic pressure losses through all fan coil unit cooling coils.

E. Witnessed Demonstrations

1. On completion of all of the foregoing on any system, or group of systems, the Commissioning Specialist shall finalise and collate the test sheets and submit a copy with a summary/witnessing sheet to the Employer.
2. The Commissioning Specialist shall demonstrate his documented figures to the witnessing team. Upon satisfactory completion of the demonstration a member of the witnessing team will countersign the summary sheet confirming that the recorded results have been witnessed.
3. Once all the foregoing checks and tests are satisfactorily completed and demonstrated, the Controls Commissioning Specialist shall normalize all distribution system and plant controls sensor set points.

F. Attendance on Manufacturers' Commissioning Specialists

1. The Commissioning Specialist shall provide attendance, as required, to demonstrate water flow rates and plant pressure losses to Manufacturers' Commissioning Specialist on items such as chillers.

3.03 COMMISSIONING AUTOMATIC CONTROL SYSTEMS

- A. Checking, setting up measurement and calibration procedures of automatic control and equipment shall be done in conjunction with the Controls Sub-Contractor.

END OF SECTION

SECTION 23 09 00

BUILDING MANAGEMENT SYSTEM (BMS)

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work under this Section of the Specifications includes all labor, materials, equipment and services to provide a fully operational native BACnet Building Management System (BMS). For terms of this specification, “native BACnet” means that all of the BMS devices, from the front end operator’s workstation to the building controllers and down to the unitary controller level, only speak and understand BACnet. The devices may be interconnected using any of the approved BACnet LAN technologies. The BMS shall be a totally native BACnet-based system, including a Microsoft Windows XP operator’s workstation, based on a distributed control system in accordance with this specification. The operator’s workstation, all building controllers, application controllers, and all input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135–2001, BACnet. No gateways shall be used for communication to controllers installed under this section. Gateways may be used for communication to existing systems or to systems installed under other sections. The work in general consists of, but is not limited to, the following:

1. The native BACnet BMS shall be as specified and consist of a high-speed, peer-to-peer network of DDC controllers and an operator workstation. The operator workstation shall be a personal computer (PC) with color monitor, mouse, keyboard, UPS, and external storage device and printer. The PC shall allow a user to interface with the network via dynamic color graphics. Each HVAC system, lighting system(s), building floor plan, and control device will be depicted by point-and-click graphics.
2. Remote portable operators interface computer units as specified.
3. A dedicated data communications network including electric isolation and protection from electrical interference.
4. A network of stand alone Direct Digital Control (DDC) controllers and field panels, including sensors, and control devices.
5. Complete electrical installation including wiring, raceways and power wiring, except as noted.
6. Software required to produce a complete and operational native BACnet BMS as specified herein. Include a minimum of two licenses for any proprietary software being provided.
7. Complete operating and maintenance manuals and field training of operators and maintenance personnel.
8. System commissioning and acceptance tests as specified.
9. Full documentation for all software and equipment provided.
10. Project management for managing system installation including, but not limited to: Design, installation, equipment delivery, and coordination with other trades, labor management, commissioning and acceptance testing.
11. Review of fire alarm shop drawing for acceptance by BMS contractor to ensure proper coordination of scope of work, wiring and operating sequences.
12. Autodial modems for communication to the control system and to remote DDC controllers or other work stations. Autodial modem shall have remote paging for pager annunciation of alarms.
13. Provision for interface wiring to fire alarm, emergency power, lighting and security systems, and other Divisions of the specifications.
14. Miscellaneous control wiring including, but not limited to:
 - a. Wiring of packaged heat pump unit thermostats
 - b. Fuel oil control system
 - c. Chiller control panel interface wiring
 - d. Boiler control panel interface wiring
 - e. Cooling tower control wiring

- f. Cooling tower level controls and filter/separator
 - g. Interlock wiring including summary alarm supervision or stand-alone systems
 - h. Power wiring from designated Division 26 outlets or circuits to BMS components that require power
- 15. Provide service kit.
 - 16. Provide spare parts as noted in this specification.
 - 17. Warranty of system including all associated materials, labor, and services for period of one year from the date of final acceptance.
 - 18. Web-based operator access software.

B. Qualification Proposal:

- 1. Submit complete proposal for review prior to final acceptance of mechanical division bid. The following information shall be submitted:
 - a. Schematic of BMS configuration indicating DDC panels, locations, capacity and functions.
 - b. List of subcontractor and supplier of components with descriptions of their services or components furnished.
 - c. Location and qualification of primary software programming support staff.
 - d. Specific detailed list of all areas of the proposed native BACnet BMS that cannot comply with the requirements of the Contract Documents. Reference the specification paragraph where compliance is not possible. Provide additional information to evaluate the impact of the deviation.
 - e. Provide all required detailed information for a satisfactory evaluation of the bid. Failure to submit may result in rejection of proposal.
- 2. Submit written resumes of key personnel proposed on the project.
- 3. The following minimum qualifications are required from the native BACnet BMS contractor.
 - a. Have comprehensive local service and trained support personnel capable of giving instruction and provide emergency maintenance on the system, including all software, firmware and hardware components.
 - b. Provide remote assistance and troubleshooting via the web based interface from contractor's office.
 - c. Have access to local supplies of essential expendable and spare parts.
 - d. Have a proven record of successful native BACnet installations and maintenance of equivalent native BACnet systems for a minimum period of 5 years.
 - e. Have installed two native BACnet systems of similar size and BMS architecture.
 - f. Provide all engineering, programming and support by a local office located within 75 miles of the project site.

1.02 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

- A. Installation of the following items furnished under this Section but installed under other sections.
 - 1. Automatic control valves
 - 2. Automatic control dampers
 - 3. Thermowells
 - 4. Airflow measuring stations
 - 5. Liquid flow sensor – transmitters
 - 6. Liquid / Steam Pressure sensor
 - 7. Liquid flow switches

- 8. VAV and fan coil type terminal unit DDC controllers
 - B. Designated circuits shall be furnished by the Division 26 Contractor from the distribution panelboards for BMS power. Power wiring from the designated power outlets or circuits shown on Division 26 drawings to BMS components shall be within the work scope of this section.
 - C. Supervise and coordinate the installation of equipment, instruments and materials furnished under this Section but installed under other Divisions of the Specifications. All equipment and instruments shall be installed in strict accordance with the manufacturer's published installation instructions.
- 1.03 PRODUCTS NOT FURNISHED OR INSTALLED BUT INTEGRATED WITH THE WORK OF THIS SECTION
- A. Chiller Controls
 - B. Boiler Controls
 - C. Variable Frequency Drives
 - D. Water Treatment Controls
 - E. Condenser Water Filtration Controls
 - F. Packaged Air Conditioners
 - G. Refrigerant Leak Detection Systems
 - H. Sump Pumps, Sewage Pumps, Domestic Water Booster Pumps
 - I. Ground Water Wells / Pumps
- 1.04 SYSTEM DESCRIPTION
- A. System Configuration:
 - 1. The Building Management System (BMS) shall perform both monitoring and control of mechanical and electrical equipment for building management, energy conservation, and environmental control.
 - 2. The BMS control philosophy shall be direct digital control and be implemented by a distributed digital system.
 - 3. The personal computer (PC) shall provide for overall building data acquisition and transfer, report generation, historical data storage and retrieval, and operator interface.
 - 4. General structure of workstation interaction shall be a standard client/server relationship. Server shall be used to archive data and store system database. Clients shall access server for all archived data.
 - 5. The server shall maintain a copy of the database and programming for each DDC panel and shall automatically reload the DDC panel over the network in the event that the DDC panel's database is lost or becomes corrupted.
 - 6. The PC shall automatically backup the DDC database daily and maintain the backup for a period of at least 6 months.
 - 7. The PC and DDCs shall communicate through dedicated communications network(s). All communications on network shall be by digital signals only. Operator's workstation shall as a minimum support Point-to-Point (PTP) and Ethernet BACnet LAN types. It shall communicate directly via these BACnet LANs as a native BACnet device. Operator's terminal shall comply with the requirements

of a BACnet conformance Class 3 device and support all BACnet services necessary to provide the following BACnet functional groups:

- a. Clock Functional Group
- b. Event Response Functional Group
- c. Time Master Functional Group
- d. Device Communications

8. The native BACnet Direct Digital Controllers shall perform remote data acquisition and process control. DDC panels shall be locally mounted completely self-contained, field programmable, real-time microprocessor based controllers shall operate stand alone in the event of a communication failure.
9. Each native BACnet DDC shall be connected to its particular controlled environment through field input/output (I/O) instrumentation.

B. Design and Performance Criteria:

1. Expansion Capability:

- a. System Point Capacity. The system size shall be expandable to at least twice the number of input/output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The PC operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system.
- b. System shall be modular to allow change of function and operation in the field by plug-in modules, equipment and software changes to expand system capacity without interrupting system operation.

2. System Performance:

- a. The system shall conform to the following minimum performance standard:
 - (1) Graphic Display: The system shall display a graphic with 20 dynamic points with all current data within 10 seconds.
 - (2) Graphic Refresh: The system shall update a graphic with 20 dynamic points with all current data within 8 seconds.
 - (3) Object Command: The maximum time between the command of a binary object by the operator and the reaction by the device shall be less than 2 seconds. Analog objects should start to adjust within 2 seconds.
 - (4) Object Scan: All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or workstation has been updated within the previous 60 seconds.
 - (5) Alarm Response Time: The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed 45 seconds.
 - (6) Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every 5 seconds. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control.
 - (7) Performance: Programmable controllers shall be able to execute DDC PID control loops at a selectable frequency of at least once per second. The controller shall scan and update the process value and output generated by this calculation at this same frequency.
 - (8) Multiple Alarm Annunciations: All workstations on the network shall receive alarms within 5 seconds of each other.

- (9) Reporting Accuracy: The system shall report all values with an end-to-end accuracy as listed or better than those listed in Table 1.
- (10) Stability of Control: Control loops shall maintain measured variable at set point within the tolerances listed in Table 2 below.

Table 1: BMS System Performance Reporting Accuracy

| Measured Variable | Reported Accuracy |
|---|------------------------------------|
| Space Temperature | ±1 degree F |
| Ducted Air | ±1 degree F |
| Outside Air | ±2 degrees F |
| Water Temperature | ±1 degree F |
| Delta-T | ±0.25 degree F |
| Relative Humidity | ±2.5 percent RH |
| Water Flow | ±5 percent of full scale |
| Airflow (terminal) | ±10 percent of full scale (Note 1) |
| Airflow (measuring stations) | ±5 percent of full scale |
| Air Pressure (ducts) | ±0.1 inches water gauge |
| Air Pressure (space) | ±0.01 inches water gauge |
| Water Pressure | ±2 percent of full scale (Note 2) |
| Electrical (A,V,W, Power Factor) | ±5 percent of reading (Note 3) |
| Carbon Monoxide (CO) | ±5 percent of reading |
| Carbon Dioxide (CO ₂) | ±50 parts per million |
| Thermal Energy | ±2 percent of reading |
| Note 1: 10-100 percent of scale | |
| Note 2: For both absolute and differential pressure | |
| Note 3: Not including utility-supplied meters | |

Table 2: BMS System Control Stability and Accuracy

| Controlled Variable | Control Accuracy | Range of Medium |
|---------------------------------|---------------------------|--------------------------------------|
| Duct Air Pressure | ±0.2 inches water gauge | 0-6 inches water gauge |
| Space Differential Air Pressure | ±0.01 inches water gauge | -0.1 to 0.1 inches water gauge |
| Airflow | ±10 percent of full scale | |
| Space Temperature | ±1.0 degrees F | |
| Duct Temperature | ±2.0 degrees F | |
| Humidity | ±5 percent RH | |
| Fluid Pressure | ±1.5 psi | 1-150 psi |
| | ±1.0 inches water gauge | 0-50 inches water gauge differential |

b. Environmental Conditions:

- (1) The native BACnet DDCs, Field Equipment Panels, and other equipment shall operate under continuous ambient environmental conditions of 35 degrees to 122 degrees F dry bulb and 10 percent to 95 percent relative humidity, noncondensing as a minimum. Sensors and control elements shall operate under the ambient environmental temperature, pressure, humidity, and vibration conditions encountered for the installed location.
- (2) Other equipment, such as video screen terminals and printers, shall, unless designated otherwise, operate properly under continuous ambient environmental conditions of 50 degrees to 104 degrees F and a relative humidity of 20 percent to 80 percent.

- c. Materials and Equipment:
 - (1) Where multiple units of the same type are required, the units shall be products of a single manufacturer, however, the component parts of the system need not be the products of a single manufacturer. The components shall not require customizing other than setting jumpers and switches and adding firmware. Each major component of equipment shall be labeled with the manufacturer's name, address, model and serial number.
 - (2) All systems and components shall have been thoroughly tested and proven in actual use.
- d. Total system shall be immune to internal and external generated sources of electrical noise.

1.05 SUBMITTALS

- A. General: Indicate at the beginning of each submittal known substitutions and deviations from requirements of the Contract Documents. Refer to Section 23 05 01 - Mechanical General Provisions.
- B. Product Data: Provide technical bulletins and catalog data for all equipment and system components. Clearly identify, by use of symbol or tag number, the service of each item. All irrelevant information shall be marked out leaving only pertinent data. For all system elements (building controller(s), application controllers, routers, and repeaters) provide BACnet Protocol Implementation Conformance Statements (PICS) as per ANSI/ASHRAE Standard 135-2001.
- C. Shop Drawings:
 - 1. Shop drawing submittals shall include sufficient data to indicate complete compliance with Contract Documents. Submissions of drawings, brochures, bulletins, catalog data, and narrative descriptions shall include as a minimum:
 - a. Symbol and abbreviation lists.
 - b. System block diagram showing quantity and location of PC, operator console equipment, native BACnet DDCs, field equipment panels and major system components.
 - c. Control diagrams for all systems controlled. Controls shall be shown on system flow diagrams.
 - d. Interfaces (software and hardware) with equipment provided in other sections of specifications.
 - e. Narrative description of operation for each system, enumerating and describing the function of each component. Include alarm and emergency sequences, and equipment interlocks.
 - f. Description of manual override capabilities.
 - g. Complete input and output point schedule. Identify point function, type and location.
 - h. Spare capacity provisions.
 - i. Detailed bill of materials.
 - j. Valve and damper schedule: Provide identification numbers, location, system, dimensions and performance data.
 - k. Device mounting details: Include as a minimum:
 - (1) Sensing elements in ducts or casings.
 - (2) Sensing elements in piping.
 - 2. Complete full-size drawings, 11-inch by 17-inch minimum using AutoCAD 2000 Software or above.

- D. Programming:
1. Point identification code.
 2. System advisory messages, printouts, logging formats.
 3. Drawings of system graphics showing monitored points.
 4. Software flow charts for application and DDC programs.
 5. Graphic User Interface program, include commands, alarm annunciation, logs and programming capabilities.
 6. Description of system operation under failure conditions.
- E. Samples:
1. Thermostat, humidity sensor and temperature sensor covers.
 2. All devices mounted on finished surfaces or exposed.
- F. Quality Control Submittals:
1. UL, FM listing compliance certificates.
 2. Final calibration, commissioning and testing reports.

1.06 OWNER'S MANUALS

- A. General:
1. Submit draft copy of Owner's manuals for review. After review by authorized representative, the Contractor shall incorporate review comments and submit 6 final copies.
 2. Update manuals with modifications made to system during guarantee period. Provide replacement pages or supplements in quantity stated above.
 3. Assemble Owner's manuals into multi-volume sets as necessary and required by the Owner.
 4. Protect each volume with a heavy duty vinyl plastic binder. Volumes to have plastic printed dividers between major sections and have oversized binders to accommodate up to ½-inch thick set of additional information.
 5. Each binder shall show the project name and volume title on front cover and spine.
 6. On the first page of each manual identify the project name, manual title, Owner's name, Engineer's name, Contractor's name, address and service phone number, and person who prepared manual. Provide a detailed table of contents for each volume of the manuals.
 7. Provide a digital copy of the manual on CD-ROM format. Document format shall be Adobe Acrobat Version 5.0 or later.
- B. Operating manual to serve as training and reference manual for all aspects of day-to-day operation of the system. As a minimum include the following:
1. Control flow diagram.
 2. Sequence of operation for automatic and manual operating modes. The sequences shall cross reference the system point names.
 3. Description of manual overrides operation of control points.
 4. System manufacturer's complete operating manuals.
 5. Troubleshooting sequence, flow diagram and procedures.
 6. Provide a digital copy of the manual on CD-ROM format. Document format shall be Adobe Acrobat Version 5.0 or later.
- C. Provide maintenance manual to serve as training and reference manual for all aspects of day-to-day maintenance and major system repairs. As a minimum include the following:
1. Complete as-built installation drawings for each system including locations on plans of all control devices drawn to scale. As-built drawings shall be submitted in

- AutoCAD format.
- 2. Overall system electrical power supply scheme indicating source of electrical power for each system component.
- 3. Indicate which components are on emergency power and indicate all battery backup provisions.
- 4. Overall system shielding and grounding scheme indicating all major components and ground paths.
- 5. Photographs and drawings showing installation details and locations of equipment.
- 6. Charts showing normal operating conditions at significant points such as electrical test points.
- 7. Routine preventative maintenance procedures, corrective diagnostic troubleshooting procedures, and calibration procedures.
- 8. Parts lists with manufacturer's catalog numbers and ordering information.
- 9. Lists of ordinary and special tools, operating materials, supplies and test equipment recommended for operation and servicing.
- 10. Manufacturer's operating set up, maintenance and catalog literature for each piece of equipment.
- 11. Recommended spare parts.
- 12. Field test reports.
- 13. Provide a digital copy of the manual on CD-ROM format. Document format shall be Adobe Acrobat Version 5.0 or later.

D. Provide Programming Manual to serve as training and reference manual for all aspects of system programming. As a minimum include the following:

- 1. Complete programming manuals, and reference guides.
- 2. Details of any special software packages and compilers supplied with system.
- 3. Information required for independent programming of system.
- 4. Documentation on application and DDC programs: Flow charts, equations, and parameters.
- 5. Point schedule; include all points, real and virtual.
- 6. Software troubleshooting procedures.
- 7. Provide a digital copy of the manual on CD-ROM format. Document format shall be Adobe Acrobat Version 5.0 or later.

1.07 QUALITY ASSURANCE

- A. The Contractor shall provide an experienced full-time Project Manager for this work, responsible for direct supervision of installation and startup of the system.
- B. Comply with all current governing codes, ordinances and regulations, as well as with requirements of NFPA, UL and all other applicable codes.

1.08 MAINTENANCE

- A. Submit an alternate price to perform complete preventative and emergency maintenance of the native BACnet BMS for a period of one (1) year in accordance with the Contractor's recommended standards and schedule. This price shall be itemized to show material costs and labor costs. This price shall be based upon work being executed during normal working hours, but shall include separate emergency callout provisions. Prices submitted should be based upon current price lists and labor rates, details of which shall be included with the bid and should be broken out into three categories.
 - 1. Computer hardware and associated equipment
 - 2. Field equipment including DDCs, sensors and final control elements
 - 3. Software and programming
- B. The preventative maintenance contract may be renewed annually, at the option of the Owner, up to a total term of 10 years. The annual price shall be negotiated 3 months in advance of

annual contract expiry and shall be at the mutual agreement of both parties. Variation in annual prices shall reflect only changes in material and labor costs as substantiated by Federal Guideline Consumer Price Indexes.

1.09 WARRANTY

- A. Labor and materials for the control system specified shall be warranted free from defects for a period of 12 months after final completion and acceptance. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner. The Contractor shall respond to the Owner's request for warranty service within 24 hours during normal business hours.
- B. All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system startup. If the work specified is split into multi-phase contract, then each contract or phase shall have a separate warranty start date and period.
- C. At the end of the final startup, testing, and commissioning phase, if equipment and systems are operating satisfactorily to the Architect and Owner the date of acceptance shall be the start of pre-warranty endurance test.
- D. Operator workstation software, project-specific software, graphic software, database software, and firmware updates which resolve known software deficiencies as identified by the Contractor shall be provided at no charge during the warranty period.
- E. After the above acceptance tests are complete and the system is demonstrated to be functioning as specified, a thirty-day endurance test period shall begin. If the system functions as specified throughout the endurance test period requiring only routine maintenance and adjustment, the system shall be accepted. If during the endurance test period the system fails to perform as specified and cannot be corrected within eight hours, the Owner may request that the endurance tests be repeated after problems have been corrected.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS OF DDC SYSTEM

- A. The base bid shall be the BACtalk system from Alerton Technologies, Inc. Other manufacturers may bid based upon meeting all requirements of the specification and receiving approval from the Architect 30 days prior to bid. A paragraph-by-paragraph comparison of base bid specified system versus alternative system along with three references of similar projects (include project name, contact, phone number, location, consultant, value of contract, and a brief description of the control system and how it operates) shall be submitted 45 days prior to bid for review process. If approved, other manufacturer's bids shall be shown as an add or deduct on the bid form.
- B. Alerton Technologies
- C. Siemens Building Technologies
- D. Automated Logic
- E. Invensys

2.02 CENTRAL CONSOLE

- A. Provide a central operator's console to include as a minimum:

1. Personal computer
 2. Color graphics display terminal
 3. Printer (alarm and logging)
 4. UPS
 5. External hard Drive
- B. Assemble console equipment in a console configuration that allows operator access to all console equipment from one position.

2.03 PERSONAL COMPUTER OPERATOR'S WORK STATION (PC)

- A. The computer shall be an IBM compatible US EPA certified Energy Star PC with the following provided:
1. Input/output ports and expansion slots: Five PCI Slots, one 4X AGP Slot, one parallel port, 4 USB-2 ports, two serial ports, one video port, audio in and out, microphone in, one keyboard and one mouse port.
 2. Intel Pentium – Intel Pentium® 4, 2.0 GHZ microprocessor.
 3. 3GB Dual Channel DDR2 RAM® of random access memory.
 4. Hard disk drive
 - a. 500GB ATA-66/100 IDE (7200 rpm) hard drive.
 - b. 500GB external hard drive
 - (1) External hard drive shall be configured to automatically backup the primary hard drive.
 5. Logitech® First Mouse™ with 2 buttons and scroll wheel.
 6. 21 inch LCD color display monitor with Energy Star rating, digital controls:
 - a. Diagonal viewable area: 20 inches minimum
 - b. Resolution: 2048 by 1536 / 75 Hz (multiscan)
 7. Graphics card: 128MB SDRAM or approved equal.
 8. DVD-Record Drive.
 9. Keyboard: 101-key typewriter-like keyboard with special function keys "F1" through "F12" and numeric keyboard. Keys to have tactile feedback. Include rubber wrist rest pad. Microsoft or equal.
 10. Color ink jet printer: 2800 by 700 dpi black and white resolution, 5 pages per minute with a 150 sheets of 11-inch by 17-inch sheet feeder, and printer cable. All change-of-state reporting, system logs, information summaries, system malfunctions and alarms shall be printed at this terminal. HP 1220 C/PS series or approved equal.
 11. Provide an internal V.90 56,600 baud fax-modem with software for remote communications.
 12. Sound card/speakers: SoundBlaster Live! Value audio card, Harmon/Kardon Speakers.
 13. Software: Microsoft® Office 2000 Small Business Edition, Windows 2000®CD with latest service pack.
 14. PC work station shall be Dell Precision ® WorkStation or Equal.
 15. The performance of the PC shall meet or exceed the recommendations of the software manufacture. If the recommended performance exceeds those listed in 23 09 00 - 2.03 the higher performance requirement shall have precedence.
- B. Uninterruptible Power Supply (UPS): Shall operate the PC and all peripherals for 30 minutes in the event of a failure of a power failure. UPS shall provide instantaneous backup power during blackouts and brownouts, lightning and surge protection tested to UL 1449, and network-grade line conditioning and two EMI/RFI filters.

2.04 LOCAL OPERATOR'S TERMINAL (LOT)

- A. Provide portable terminal(s) to allow local programming, control and monitoring at each DDC panel.
- B. Provide one (1) portable LOT which can be connected to any DDC panel.
- C. The portable LOT shall meet the following requirements:
 - 1. Portable Operator's Terminal. Furnish a LOT that shall be capable of accessing all system data. Also provide a network connection tool that shall allow technician to connect a laptop PC to any MS/TP network or at any MS/TP device and view and modify all information throughout the entire BACnet network. Laptop PC connection to tool shall be via Ethernet or PTP. The Portable Operator's Terminal shall be an IBM compatible notebook-style PC including all software and hardware required. The PC shall contain at minimum:
 - a. Pentium® 4 Processor, 1.6 GHz with 13.3-inch TFT XGA Display
 - b. 1 GB of RAM
 - c. 250 GB hard drive
 - d. Wi-Fi Ethernet
 - e. Modem and NIC card: Ethernet 10/100 plus Modem 56
 - f. CD-RW drive
 - g. Touch-pad or other internal pointing device
 - h. 4 USB-2 ports, one serial port
 - i. Audio in and out
 - j. Dell Latitude or equal

2.05 NATIVE BACNET DIRECT DIGITAL BUILDING CONTROLLER

- A. Native BACnet DDC Building Controllers shall be completely self-contained, field programmable, real time 32-bit microprocessor based controllers.
- B. DDC application programs shall be resident in the DDC. Once downloaded, a DDC shall not require further communication with the CPU except for data base changes, operator commands, and requests from the CPU for DDC data.
- C. The Building Controller shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP network, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the LAN. Must support interoperability on wide area networks (WANs) and campus area networks (CANs) and function as a BACnet Broadcast Management Device (BBMD).
- D. Building Controller shall as a minimum support Point-to-Point (PTP), MS/TP and Ethernet BACnet LAN types. It shall communicate directly via these BACnet LANs as a native BACnet device and shall support simultaneous routing functions between all supported LAN types. Global controller shall be a BACnet conformance Class 3 device and support all BACnet services necessary to provide the following BACnet functional groups:
 - 1. Clock Functional Group
 - 2. Files Functional Group
 - 3. Reinitialize Functional Group
 - 4. Device Communications Functional Group
 - 5. Event Initiation Functional Group
- E. Provide current and voltage limiting devices at communications network cable connection.
- F. Provide power supplies with transient power line surge protection.

- G. Supply a minimum of 72 hours of battery backup for the random access memory and real time clock. Provide automatic restart and battery recharging upon restoration of power.
- H. Provide floor mounted or wall mounted cabinet with full front-hinged door, locking handle with master key and non-glare baked enamel finish. Each DDC shall contain a clear plastic encased control diagram showing associated controls.
- I. Provide the manufacturer's standard enclosure except if location requires additional protection due to potential vandalism, environmental conditions or any other reason. Take all necessary precautions to protect the DDC and related components, including:
 - 1. Using suitable NEMA enclosure
 - 2. Heavy-duty key locks
- J. Capabilities:
 - 1. Stand-Alone Capability: If PC or communications network malfunctions, each DDC shall continue to control, monitor and have the ability to be accessed and programmed via the LOT.
 - 2. Degraded Mode: If failure of a sensor or system component causes information critical to a DDCs program to be lost, default values or subroutines shall automatically be used to approximate critical information to ensure continued control.
 - 3. Networking: Each DDC shall share point information with other DDCs on the same data network.
 - 4. Real time operating system shall execute a of time-of-day scheduling and other time based functions.
 - 5. Unauthorized access to hardware or software programs shall be accomplished by a password or cabinet lock. In the locked or unauthorized position, the operating characteristics of the DDC cannot be changed, although inputs, outputs and set point values can be displayed. In the unlocked or authorized position, the ability to change the DDC program shall be unhindered.
 - 6. Alarm processing shall include: Change of state, flow proof, high and low analog limits, and setpoint deviation. Provide at least two levels of alarm priority.
 - 7. The DDC programming language shall be designed for Building Automation and Control applications and shall be capable of performing the following control algorithms: Floating; Proportional (P) direct and reverse acting; Proportional plus Integral (PI); Proportional Integral plus Derivative (PID); Anti-integral wind up; Cascade; programmed interlock logic; deadband switching and control; incremental control.
 - 8. All communication with operator workstation and all application controllers shall be via BACnet. Building controller shall incorporate as a minimum, the functions of a 3-way BACnet router. Controller shall route BACnet messages between the high-speed LAN (Ethernet 10/100MHz), at least 4 master slave token passing (MS/TP) LANs, a point-to-point (PTP – RS-232) connection and an on-board modem.
 - a. Each MS/TP LAN shall be software configurable from 9.6 to 76.8Kbps.
 - b. The RJ-45 Ethernet connection shall accept either 10Base-T or 100Base-TX BACnet over twisted pair cable (UTP).
 - c. The direct access port shall be a female DB-9 connector supporting BACnet temporary PTP connection of a portable BACnet operator terminal at 9.6 to 115.2 Kbps over RS-232 null modem cable.
- K. DDC Configuration:
 - 1. Points used in the same control loop or algorithm shall be connected to the same DDC.
 - 2. Spare Capacity: Allow for 10 percent increase of each point type per DDC location, or a minimum of two of each point type per DDC location whichever is greater. Addition of points shall require only programming, control devices and wiring.

3. Programming shall be object-oriented using control function blocks, supporting DDC functions, 1000 Analog Values and 1000 Binary Values. All flowcharts shall be generated and automatically downloaded to controller. Programming tool shall be resident on workstation and the same tool used for all controllers.
4. Building controller shall provide a global control strategy for the system based on information from any objects in the system regardless if the object is directly monitored by the controller or by another controller. The program that implements these strategies shall be completely flexible and user definable. Any systems utilizing factory pre-programmed global strategies that cannot be modified by field personnel on-site or downloaded via remote communications are not acceptable. Changing global strategies via firmware changes is also unacceptable.

2.06 NATIVE BACNET CUSTOM APPLICATION CONTROLLERS (CAC)

- A. General: Provide an adequate number of native BACnet Custom Application Controllers to achieve the performance specified in the Part 1 of this section on system performance. Each of these controllers shall meet the following requirements.
 1. The Custom Application Controller shall be native BACnet and have sufficient memory to support its operating system, database, and programming requirements.
 2. Data shall be shared between networked Custom Application Controllers.
 3. The operating system of the Controller shall manage the input and output communication signals to allow other distributed controllers to share real and virtual object/point information, and allow central monitoring and alarms.
 4. Controllers that perform scheduling shall have a real-time clock.
 5. The Custom Application Controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall operate under a predetermined failure mode and generate an alarm notification to the BMS network.
- B. Environment:
 1. Controller hardware shall be suitable for the anticipated ambient conditions.
 2. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures, and shall be rated for operation at -40 degrees F to 150 degrees F.
 3. Controllers used in conditioned space shall be mounted in dust-proof enclosures, and shall be rated for operation at 32 degrees F to 120 degrees F.
- C. Keypad: A local keypad and display shall be provided for interrogating and editing data. A system security password shall be available to prevent unauthorized use of the keypad and display.
- D. Serviceability: Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
- E. Memory: The Custom Application Controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
- F. Immunity to power and noise: Controller shall be able to operate at 90 percent to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hertz and from keyed radios up to 5 watts at 3 feet.

2.07 NATIVE BACNET APPLICATION SPECIFIC CONTROLLERS

- A. General: Application Specific Controllers (ASCs) are microprocessor-based native BACnet DDC controllers, which through hardware or firmware design are dedicated to control a

specific piece of equipment. ASCs shall be user-programmable, and customized for operation within the confines of the equipment they are designed to serve. Application Specific Controllers shall communicate with other controllers on the internetwork.

- B. Each ASC shall be capable of standalone operation and shall continue to provide control functions without being connected to the network.
- C. Each ASC shall contain sufficient I/O capacity to control the target system.
- D. Communication:
 - 1. The controller must reside on a BACnet network using the MS/TP Data Link/Physical layer protocol. All controllers shall interface to building controller via MS/TP LAN using BACnet protocol. No gateways shall be used. Controllers shall include input, output and self-contained logic program as needed for complete control of unit.
 - 2. Each controller shall have compatible connection for a LOT or a portable operator's tool. This connection shall be extended to a space temperature sensor port where shown.
- E. Environment:
 - 1. The hardware shall be suitable for the anticipated ambient conditions.
 - 2. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures, and shall be rated for operation at -40 degrees F to 150 degrees F.
 - 3. Controllers used in conditioned space shall be mounted in dust-proof enclosures, and shall be rated for operation at 32 degrees F to 120 degrees F.
- F. Serviceability: Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
- G. Memory: The Application Specific Controller shall use non-volatile memory and maintain all BIOS and programming information in the event of a power loss.
- H. Immunity to Power and Noise: Controllers shall be able to operate at 90 percent to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent. Operation shall be protected against electrical noise of 5-120 Hertz and from keyed radios up to 5 watts at 3 feet.
- I. Transformer: Power supply for the ASC shall be rated at minimum of 125 percent of ASC power consumption, and shall be fused or current limiting type.
- J. Hardwired inputs and outputs shall tie into the system through building, custom application, or application specific controllers.
- K. The ASC shall provide the following information either on the PC or the LOT unit.
 - 1. Space temperature/humidity
 - 2. Space temperature set point(s) for heating and cooling
 - 3. Minimum primary air set point
 - 4. Maximum primary air set point
 - 5. Valve and damper positions in percent open
 - 6. Air volume in cubic feet per minute
 - 7. Fan status for fan powered terminal unit (if applicable)
 - 8. Control parameters (deadbands, PID gains, etc.)

2.08 LIGHTING CONTROLS

A. Description:

1. ~~General: Provide an interface to the BMS for the control of lighting zones, relays and circuits as indicated on the electrical drawings and specifications. Refer to electrical drawings for location of relay panels and lighting zone quantities.~~
2. ~~Related work specified elsewhere:~~
 - a. ~~Provision of switches, controller, lighting relay cabinets and relays (LRC) by Division 26.~~
 - b. ~~Provision of branch circuit wiring from lighting fixtures circuit breakers to relays and from relays to switches by Division 26.~~
 - c. ~~Provision of interface module using Modbus, BACNet or Lonworks communications protocol.~~
3. ~~Control wiring and wireways from BMS system to lighting control interface module.~~
4. ~~Provision of necessary controllers, network connections, programming and graphics.~~

B. Submittals:

1. ~~Provide shop drawing submittals complete with the following information.~~
 - a. ~~Wiring diagrams of each interface module/lighting relay cabinet interconnection.~~
 - b. ~~Description of each device/component, including cut sheets.~~
 - c. ~~Lighting control zoning diagram.~~
2. ~~Provide a narrative describing the software function of the system.~~

C. Sequence of Operation:

1. ~~Each lighting zone shall be individually programmable to switch lights on and off in accordance with time schedules determined by the Owner. Coordinate with the Owner to determine initial lighting schedules.~~
2. ~~Sequence shall include a momentary flashing of the lights on and off to signal occupants to initiate an override command at the local switch. Build in an adjustable time interval before turning off lights after flashing sequence.~~
3. ~~Exterior lighting shall be controlled as separate zones and switched on and off in accordance with time schedules or with an input from a photocell.~~
4. ~~All lighting zones shall be manually commanded by the BMS operator to override the automatic software status.~~

D. Testing and Start Up:

1. ~~Provide operational test report in matrix form indicating each lighting zone showing successful operation of the automatic control sequence.~~

2.08 INPUT AND OUTPUT INTERFACE

- A. All input points and output points shall be protected such that short circuiting of the point to itself or to another point, or to ground will cause no damage to the controller. All input and output points shall be protected from voltage up to 24 volts of any duration, such that contact with this voltage will cause no damage to the controller. Inputs and outputs shall be arranged on interchangeable modules or circuit boards to allow the replacement of a damaged module or board without replacing the entire controller.
- B. Binary inputs shall allow the monitoring of On/Off signals from remote devices. The binary

inputs shall provide a wetting current of at least 12 milliamps to be compatible with commonly available control devices, and shall be protected against the effects of contact bounce and noise. Binary inputs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.

- C. Pulse Accumulation Input Objects: This type of object shall conform to all the requirements of binary input objects, and also accept up to 10 pulses per second for pulse accumulation.
- D. Analog inputs shall allow the monitoring of low-voltage (0 to 10 volts DC), current (4 to 20 milliamps), or resistance signals (thermistor, RTD). Analog inputs shall be compatible with, and field-configurable to commonly available sensing devices.
- E. Binary outputs shall provide for On/Off operation, or a pulsed low voltage signal for pulse width modulation control. Binary outputs on Building and Custom Application Controllers shall have three-position (On/Off/Auto) override switches and status lights. Outputs shall be selectable for either normally open or normally closed operation.
- F. Analog outputs shall provide a modulating signal for the control of devices. Outputs shall provide either a 0 to 10 volts DC or a 4 to 20 milliamp signal as required to provide proper control of the output device. Analog outputs on Building or Custom Application Controllers shall have status lights and a two-position (AUTO/MANUAL) switch and manually adjustable potentiometer for manual override. Analog outputs shall not exhibit a drift of greater than 0.4 percent of range per year.
- G. Tri-State Outputs: Provide tri-state outputs (two coordinated binary outputs) for control of three-point floating type electronic actuators without feedback. Use of three-point floating devices shall be limited to zone control and terminal unit control applications (VAV terminal units, duct mounted heating coils, zone dampers, radiation, etc.). Control algorithms shall run the zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.
- H. Input/Output points shall be universal type, i.e., controller input or output may be designated (in software) as either a binary or analog type point with appropriate properties. Application Specific Controllers are exempted from this requirement.

2.09 POWER SUPPLIES

- A. Control transformers shall be UL listed. Furnish Class 2 current-limiting type, or furnish over-current protection in both primary and secondary circuits for Class 2 service per NEC requirements. Limit connected loads to 80 percent of rated capacity.
- B. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 millivolt maximum peak-to-peak. Regulation shall be 1.0 percent line and load combined, with 100 microsecond response time for 50 percent load changes. Unit shall have built-in over-voltage and over-current protection, and shall be able to withstand a 150 percent current overload for at least 3 seconds without trip-out or failure.
- C. Unit shall operate between 0 and 50 degrees C. EM/RF shall meet FCC Class B and VDE 0871 for Class B, and MIL-STD 810C for shock and vibration.

2.10 SENSORS AND CONTROL DEVICES

- A. General:
 - 1. Provide sensors and control devices, as specified, indicated on mechanical plans, control flow diagrams and as required to meet specified performance. Where performance specifications exceed capabilities of hardware specified, performance governs. The installation of such devices, if not specifically indicated, shall be the

- responsibility of the Contractor.
2. Equip analog sensors with industry standard 4 to 20 milliamp transmitters with built-in circuit protection against reverse polarity and supply voltage transients. The transmitters shall be matched to the sensing element and compatible with the DDC Building Management System.
 3. All sensor/transmitters assemblies shall be factory calibrated.
 4. All sensor wiring, analog or digital, input or output shall be capable of sharing single conduit runs without affecting signal performance. All signal wiring shall also be capable of sharing single conduit runs with switched AC of 120 or 277 volts.
 5. The sensor range and type shall be suitable to the application.
 6. Minimum contact rating of relays and switches shall be 10 amperes, 110 volts resistive.
 7. Relays shall have an LED indicator light to show when coil is energized.
 8. Devices shall be UL listed for electrical safety where applicable.
 9. All components of sensors exposed to process shall be rated to withstand 150 percent of maximum process temperature and pressure.
- B. Thermowells: Provide Type 316 stainless steel thermowells for each immersion type temperature sensor and switch. Thermowells shall have extension for pipe insulation and threaded connection to pipe. Threaded connection shall be a minimum of ¾-inch nominal pipe thread. Maximum insertion length shall be 6 inches or 75 percent of the pipe diameter whichever is smaller.
- C. Temperature Sensors:
1. Temperature sensor assemblies shall consist of a 100 or 1,000 ohm platinum RTD sensor and a solid state, 2-wire, 4- to 20-milliamp transmitter protected in a housing suitable for the environment in which it is installed.
 2. Acceptable Manufacturers: Weksler Model T4, Weiss Model EN or acceptable equivalent.
 3. Sensor accuracy shall be plus or minus 1.0 degree F except for chilled water temperature applications the accuracy shall be plus or minus 0.5 degrees F.
 4. Sensors for mixed air and coil discharge applications and for fan discharge applications in systems over 5,000 cubic feet per minute shall be averaging type sensors. Probe lengths shall be minimum one linear foot per four square feet of duct or coil area or equal to duct, plenum or AHU casing width where installed, whichever is longer.
 5. Outside air sensors:
 - a. Outdoor air sensors shall be protected from the effects of solar radiation and vandalism.
 - b. Outdoor air sensors shall installed sufficiently far from building exhaust so as to prevent any temperature influences.
 - 6.
- D. Humidity Sensors:
1. Humidity sensor assemblies shall consist of a capacitive or bulk polymer type sensor and a solid state four to twenty milliamp transmitter protected in a housing suitable for the environment where it is installed.
 2. Provide low profile sensor housing 1-inch diameter by 0.35-inch thick.
 3. Performance:
 - a. Accuracy at 77 degrees F: plus or minus 1 percent relative humidity over a range of 20 to 95 percent relative humidity including hysteresis, linearity and repeatability.
 - b. Temperature effect: Less than 0.06 percent per degree F.
 - c. Sensitivity: 0.1 percent relative humidity.

- d. Hysteresis: Less than 1 percent.
 - e. Sensor interchangeability: Plus or minus 3 percent nominal.
 - f. Air velocity: 10,000 feet per minute maximum.
 - g. Output: 4 to 20 milliamps, isolated, loop-powered into 0 to 99 ohms.
 - h. Long term stability: Less than 1 percent drift per year.
- 4. Provide cable to transmitter as required. Locate transmitter in an accessible location.
 - 5. Acceptable manufacturers: General Eastern, Vaisala.
- E. Flow Transmitter Assembly – Water (Ultrasonic):
- 1. Insertion style magnetic flow sensor that features no moving parts.
 - 2. Constructed of corrosion-resistant materials to provide long-term reliability with minimal maintenance costs.
 - 3. Covers a range in pipe sizes ranging from DN15 to DN300 (0.5 to 12 inches)
 - 4. Output options of frequency/digital (S₃L), 4 to 20 mA or relays which are available on both the blind and display versions.
 - 5. The frequency or digital (S₃L) sensor output shall be used with Signet's extensive line of flow instruments while the 4 to 20mA output can be used for a direct input to PLCs, chart recorders, etc.
 - 6. Both the 4 to 20 mA output and digital (S₃L) sensor interface is available for long distance signal transmission of up to 1,000 ft.
 - 7. Empty pipe detection which shows a zero flow output when the sensors are not completely wetted.
 - 8. Frequency output is bi-directional while the 4 to 20mA output can be set for uni- or bi-directional flow using the display or the RS232 set-up tool which connects to PCs for programming capabilities.
 - 9. Flow rate range: 0.05 to 10 m/s (0.15 to 33 ft/s)
 - 10. Acceptable Manufacturers: Signet 2551 Magmeter Flow Sensor
- F. Flow Measuring Probe – Air (Thermal):
- 1. Probe shall consist of a thermistor or platinum RTD type air measuring station with a low resistance copper or aluminum frame containing an array of sensors spaced four per square foot as per ASHRAE standards, with a solid-state, 4- to 20-milliamp transmitter.
 - 2. The probe shall be factory calibrated and field installed to an accuracy of plus or minus 2 percent of airflow over a range of 200 to 3000 feet per minute. Repeatability shall be plus or minus 0.25 percent.
 - 3. All electronics shall be housed in a NEMA 1 enclosure and mounted in accordance with manufacturer's recommendations.
 - 4. Acceptable Manufacturers: Ebtron (Gold Series).
- G. Pressure Transmitter Assembly – Air Streams:
- 1. The assembly shall consist of a pressure sensor and a solid-state, 2-wire, 4- to 20-milliamp transmitter contained in a housing suitable for duct mounting.
 - 2. The assembly shall be factory calibrated and field installed to an accuracy of plus or minus 0.05 inches water gauge over a range of 0 to 4 inches water gauge.
 - 3. Probe: 8-inch pitot tube, brass.
 - 4. Acceptable Manufacturers: Brandt, Setra, Air Monitor.
- H. Differential Pressure Transmitter Assembly – Water:
- 1. Assembly shall consist of a differential pressure sensor and an electronic 2-wire, 4- to 20-milliamp transmitter assembly enclosed in a gasketed, dust and watertight case. All body cavities open to the process fluid shall be provided with drain ports at

the cavity bottom and vent ports at the top of the cavity. Both drain and vent ports shall be minimum ¼-inch nominal pipe thread.

2. The transmitter shall be 24-volt DC powered and capable of sustaining up to 50 psig differential pressures in either direction, up to the body rating without damage of the instrument, loss of accuracy, or zero shift. Minimum pressure rating: 200 psig.
3. The transmitter shall be fully compensated for both process and ambient temperature variations. The transmitter shall be furnished complete with input gauges and factory mounted 3-valve manifold.
4. Accuracy: Plus or minus 1 percent of full range.
5. Repeatability: 0.5 percent.
6. Acceptable Manufacturers: Mamac PR-282 or acceptable equivalent.

I. Demand Control Ventilation Sensor:

1. CO₂ Sensors and Transmitters: Provide a self-compensating, return air duct mounted CO₂ transmitter with an industry standard, 4-20 ma output signal. Measurement range to be 0 to 2000 ppm with an accuracy of $\pm 20\text{ppm} + 1$ percent of reading and a stability of <5 percent in 5 years. Locate the sensors to be as shown on the drawings. Transmitter shall be by Vaisala – GMD20 Series.

J. Current Sensing Switches:

1. Current switches shall produce a digital signal corresponding to the current draw of the device being monitored, and such signal shall be scaled in amperes. Current switches shall incorporate an automatic adjustment feature and be sized such that the rated current of the device to be monitored is between 20 percent and 80 percent of the maximum current transducer. Current measurement precision shall be ± 0.1 amp, and a current accuracy shall be ± 2 percent of range. Veris or equal.
2. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
3. Current switches used for VFD applications shall automatically calibrate using micro processor technology and shall detect belt loss from 35-60Hz on VFD applications;

K. Differential Pressure Switch – Liquid:

1. Provide completely enclosed contact mechanism.
2. Switch differential setpoint shall be adjustable without removing the cover.
3. Maximum differential pressure of 200 psig.
4. Maximum low side pressure of 180 psig.
5. Bellows shall be stainless steel.
6. Acceptable Manufacturers: JCI/Penn Model P74, Barksdale EPDI or acceptable equal.

L. Differential Pressure Switch – Air:

1. Provide diaphragm operator to actuate a single-pole double-throw snap-acting switch. Operating point shall be adjustable. Range shall suit application.
2. High and low sensing ports shall be 1/8-inch nominal pipe thread connected to angle type tips designed to sense pressure.
3. Switches used for fan shutdown shall be manual reset type.
4. Acceptable Manufacturers: Cleveland Controls Model AFS 3152 or acceptable equal.

M. Damper End Switch:

1. Provide oil-tight, roller type, single pole double throw snap-acting switch. Mechanism to provide ample overtravel to prevent stress on damper and control equipment.
2. Acceptable Manufacturers: Furnas Electric, Allen Bradley, Telemecanique.

- N. Low Limit Thermostat: Shall have a 20-foot flexible vapor charged element. When temperature sensed by any 12-inch segment of the element falls below setpoint (usually 35 degrees F), thermostat shall operate double-pole double-throw manual reset contacts.

2.11 AUTOMATIC DAMPERS

- A. Provide automatic dampers as indicated on Drawings as either automatic dampers or automatic louver dampers.
- B. Dampers shall be low leakage type, with published AMCA certified leakage data. Leakage through a 48-inch by 48-inch damper at 4 inches water gauge pressure difference shall be less than 6.2 cubic feet per minute per square foot of damper.
- C. Damper blades and frames shall be fabricated from extruded aluminum, reinforced for rigidity. Blades shall be of airfoil design with full-length edge seals with inflatable pockets to enable air pressure from either direction to assist in blade seal off. Edge seals shall be mechanically locked to the blades locked without the use of cement but easily replaceable in the field. Edge seal material shall meet all local codes and requirements of city officials. Bearings shall be non-corrosive and axles shall provide positive locking connection to blades and linkage. Blades mounted vertically shall be supported by thrust bearings. Jamb seals shall be aluminum, flexible compression type.
- D. Dampers used for modulating control application shall be of opposed blade configuration and dampers used for open/closed applications shall be parallel blade type.
- E. Dampers shall have a maximum blade length of 48 inches and a maximum blade width of 8 inches. The maximum height of each damper section shall be 72 inches. Where greater length or height is required, provide an assembly of multiple damper sections.
- F. Install damper actuators of sufficient quantity and size to limit leakage to specified rate. Damper assemblies consisting of multiple damper sections shall be provided with a minimum of one damper actuator per section or be connected with an approved jack-shafting arrangement.
- G. Acceptable Manufacturers: Ruskin, Pottorff, Air Balance, Johnson Controls.

2.12 HEAVY DUTY INDUSTRIAL AUTOMATIC DAMPERS

- A. Provide heavy-duty automatic dampers as indicated on Drawings for variable volume manifolded laboratory fume exhaust systems bypass pressure control.
- B. Dampers shall be rated at 4,000 feet per minute duct velocity. Leakage through a 60-inch wide damper at 12 inches water gauge pressure difference shall be less than 4.0 cubic feet per minute per square foot of damper.
- C. Damper blades and frames shall be fabricated from 14-gauge Type 316 stainless steel. Blades shall be of airfoil design with full-length EDPM edge seals. Edge seals shall be mechanically locked to the blades locked but easily replaceable in the field. Bearings shall be stainless steel sleeve bearings in cast housing bolted to the frame. Axles shall be Type 316 stainless steel, 3/4-inch diameter. Jamb seals shall be compression type.
- D. Dampers shall be of opposed blade configuration.
- E. Install damper actuators of sufficient quantity and size to limit leakage to specified rate. Damper assemblies consisting of multiple damper sections shall be provided with a minimum of one damper actuator per section.
- F. Acceptable Manufacturers: Ruskin Model CD80AF2 or equal.

2.13 MODULATING AIRFLOW MONITOR DAMPER

- A. Provide integral air monitor and damper to control the minimum amount of outside air. Damper shall be mounted in an aluminum frame. Damper blades shall be heavy gauge aluminum airfoil type with "neoprene" equivalent blade edge seals. Jamb seals shall be flexible metal compression type.
- B. Air monitor damper shall incorporate an air straightener section to ensure proper airflow readings.
- C. Air monitor damper shall be provided with a 24-volt AC modulating motor and an application specific digital controller designed for the damper and provided by the damper manufacturer. Airflow damper shall be calibrated in an AMCA laboratory and calibration certification shall be included with the damper.
- D. The damper application specific controller shall provide a 0-10 volt DC output representative of actual airflow. The controller shall accept a 0-10 volt DC input from the BMS representing a cfm flow setpoint adjustment.
- E. Acceptable Manufacturers: Ruskin Model IAQ50 damper or equal.

2.14 AUTOMATIC VALVES

- A. Automatic control valves shall be globe type with modulating plug, throttling guides, replaceable seats and discs, and stainless steel stems.
- B. Valves 2-inch and smaller shall have bronze bodies with screwed ends. Valves 2½-inch and larger shall have iron bodies with flanged ends.
- C. Valve body rating shall be equal or greater than the piping in which it is installed and the valve shall be rated for operation against the minimum system differential pressure. Rangeability shall be at least 40 to 1 or as required to provide proper control. Leakage shall not exceed 0.1 percent for single seated valves and 1 percent for double-seated valves.
- D. Characteristics:
 - 1. Chilled Water Service: Equal percentage flow characteristics, single seated type.
 - 2. Isolation Service: Linear flow characteristics. Single or double seated.
- E. Valve Action:
 - 1. Cooling valves normally closed.
 - 2. Or as noted or specified.
- F. Size valves to meet the coil loads as specified and as follows:
 - 1. 2-Position Valves: Line size unless noted.
 - 2. Water Service: Maximum pressure drop shall be equal to the pressure drop of the associated coil or exchanger, or 5 pounds per square inch whichever is greater.
 - 3. Cooling Tower Bypass Valves: Sized according to pressure available.
 - 4. Chilled Water Service: Where load exceeds capacity of 4-inch control valve provide two valves piped in parallel and operating in sequence. The larger valve shall have a coefficient of flow (Cv) that is between 2 and 3 times larger than the smaller valve.

2.15 AUTOMATIC ELECTRIC DAMPER/VALVE ACTUATORS

- A. The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator.

- B. Where shown, for power-failure/safety applications, an internal mechanical, spring-return mechanism shall be built into the actuator housing.
- C. All rotary spring-return actuators shall be capable of both clockwise and counter-clockwise spring-return operation. Linear actuators shall spring-return to the retracted position.
- D. Proportional actuators shall accept a 0- to 10-volt DC or 0- to 20-milliamp control signal and provide a 2- to 10-volt DC or 4- to 20-milliamp operating range.
- E. All 24-volt AC/VDC actuators shall operate on NEC Class 2 wiring and shall not require more than 10 volt-amperes for AC or more than 8 watts for DC applications. Actuators operating on 120 volts AC or 230 volts AC shall not require more than 11-volt-amperes.
- F. All non-spring-return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring-return actuators with more than 60 inch-pounds torque capacities shall have a manual crank for this purpose.
- G. All modulating actuators shall have an external, built-in switch to allow the reversing of direction of rotation.
- H. Actuators shall be provided with a raceway fitting and a minimum 1m electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.
- I. Actuators shall be UL Standard 873 Listed and CSA Class 4813 02 Certified as meeting correct safety requirements and recognized industry standards.
- J. Actuators shall be designed for a minimum of 60,000 full-stroke cycles at the actuator's rated torque.
- K. Actuators shall have visual mechanical position indication, showing output shaft and valve position. The actuator shall be capable of operating the valve from the fully closed to the fully open position and vice versa in less than 60 seconds.
- L. Acceptable Manufacturers: Siemens, Belimo Aircontrol.

2.16 BUTTERFLY VALVES

- A. Butterfly valves are permitted for use for two-position operation on low temperature water applications only.
- B. All butterfly valves shall be of the full lug body style with lugs drilled and tapped and have drip tight shutoff capabilities in either direction up to and including maximum system working pressure. Butterfly valves shall be capable of closing tight after long periods of inactivity.
- C. All valves shall be suitable for use with ANSI Standards flanges. Bodies shall be semi-steel or cast iron.
- D. Valves shall provide tight shutoff up to the full valve rating on dead end or isolation service without the use of downstream flanges.
- E. All valves shall be furnished with self-lubricated bronze bearings. Shafts seals shall be provided to prevent leakage and to protect bearings from internal or external corrosion.
- F. Seats shall be of the reinforced resilient type (or retained seat on high performance valves) and shall also act as a body liner to prevent flow from contracting the body casting. Resilient seats shall have flange sealing lips to provide a positive seal without use of flange gaskets.

- G. Seats shall be Nordel suitable for use with HVAC water to 250 degrees F. Shafts shall be one piece, machined from Type 416 stainless steel, finish ground and polished to minimize bearing and shafts seal wear. Shafts of 8-inch and larger valves shall have a non-adjustable thrust collar.
- H. Discs shall be semi-steel with welded nickel edge. The disc-to-shaft connections shall be type 316 stainless steel. Pins, shaft and disc of all valves shall be individually machined and completely interchangeable.
- I. Valves shall be line size unless otherwise noted on Drawings.
- J. Acceptable Manufacturers: Bray

2.17 FIBER OPTIC CABLE SYSTEM

- A. Optical Cable: Optical cables shall be duplex 900-millimeter tight-buffer construction designed for intra-building environments. The sheath shall be UL Listed OFNP in accordance with NEC Article 770. The optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125 millimeter.
- B. Connectors: All optical fibers shall be field-terminated with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

2.18 SERVICE KIT

- A. Provide three service kits for use by Owner in testing and making minor service adjustments to the system. Include as a minimum:
 - 1. All specialized nonstandard tools and adapters and fittings required for operating, maintaining, testing and adjustment of the system.
 - 2. Keys for thermostats and humidity control, two per kit.
 - 3. Lubricant required for automatic valves and automatic dampers, one year supply.

2.19 SPARE PARTS

- A. Provide to the Owner 1 spare part for every 20 installed, but not to exceed 5 spares:
 - 1. Excluding
 - a. Controllers
 - b. Valve Bodies
 - c. Dampers

2.20 SOFTWARE

- A. General:
 - 1. Fully implement, optimize, and commission all software described under this paragraph and required for a complete operable system.
 - 2. Although "Program" implies software, hardware solutions may be acceptable after review and approval of authorized representative. Such differences shall be considered deviations and presented as such.
 - 3. Software programs are described as to general intent. It is recognized that BMS contractors' software differ; however, the programs that are provided shall incorporate the features described.
 - 4. Each point shall be identified in software with a unique point name of not less than 8 alphanumeric characters. Point names shall be logically and consistently coded to allow identification of the point location (e.g., Building, MER), associated HVAC

system (e.g., AHU-1, Chiller-2), and point function (e.g., supply temp, freezestat) as a minimum. Coordinate point naming convention with Owner

B. Executive Software:

1. The executive software shall include all programs required for systems, applications, peripheral devices and communications networks.
2. Restrict user software modifications to insure system security. User access to the executive software shall be provided as follows:
 - a. Ability to switch failing output devices to another device without loss of data or otherwise handle device failures (e.g., jammed printers).
 - b. Ability to modify the priorities and scheduling of application programs.
 - c. Ability to add or delete peripheral devices.
3. Provide diagnostic programs to report and display DDC system failures at the Operator's console both on video display and printer. Provide on-line error detection and messages for the discs, power supplies, CPUs, communications boards, and peripherals. Upon failure of a video display system, the system shall be operable using the printers and keyboard.
4. Provide a software time clock which shall display date, time information where required to resolution of one second and otherwise supply data to programs at resolution of 0.1 seconds; display real time clock in 12 hours or 24 hours format and date. Time and date shall be resettable by mouse or keyboard entry.
5. Peripheral Equipment Selection:
 - a. Provide peripheral equipment selection control to apportion data to peripheral console as required (e.g., alarms to alarm printer).
 - b. Apportionment of data and control functions shall be a programmable function by an authorized operator at any console. Initialization of the apportionment of data shall be according to the description of the functional requirements stated under each console description. Contractor shall provide all software and programming time required to initialize the system. Submit initial apportionment for all monitored and control functions for review prior to final programming.
 - c. The graphics display shall allow simultaneous operator interaction and alarm indication in separate on-screen windows.
6. System Access Control: Provide a minimum of three levels of access using selectable passwords to the system software. Each higher level will increase the allowed interaction by the user. Each password must be entered by the operator to access a particular level of system operation. The password shall not be displayed or printed. Each password shall be unique for each operator.
7. The system shall observe the following command priorities (from highest to lowest):
 - a. Smoke Control and Life Safety
 - b. Manual Operator Command
 - c. Energy Management
 - d. Automatic Control

C. Operator Interface Program:

1. Provide Microsoft Windows© compatible software as the operator interface with the BMS for defining and selecting points, parameters, report generation, graphics, time schedules and all functions associated with day-to-day operation of the system.
2. Provide software to notify the operator of the occurrence of an alarm condition. All alarm messages displayed on the video terminal, on the local printer, and on the remote printer shall be in simple English-language format. System shall print and sound an audible alarm at each occurrence. Operator acknowledgement shall

- silence the audible alarm. System shall print upon return to normal.
3. Report generation software shall be provided to present system information in an organized manner:
 - a. System Point Log: A log for each system shall include all points required for operation and monitoring of the system. Do not include points used in intermediate calculations and program logic or points used for system tuning and set up.
 - b. Display for each point: Point Name, Point Description, Current Value, Engineering Units, Alarm Status and Command Priority.
 - c. Application program logs: Log for each program shall include current values of all points and parameters used in application program.
 - d. Summary logs: Logs shall summarize system status. Include as minimum:
 - (1) Alarm summary
 - (2) Run time totalization summary
 - (3) Disabled point summary
 4. Provide fully implemented interactive graphics with latest available process data fully integrated with the display. Point values shall be dynamically updated at an operator selectable rate from 5 to 120 seconds. Or based on a Change of Value threshold.
 - a. Provide a minimum of 32 different operator selectable colors for the various system components to facilitate rapid recognition and ease of interaction. Colors shall be uniform on all displays, such as all master alarms red blinking with reverse field.
 - b. Graphics generation and editing shall be via Windows© based mouse-operated interactive software. The graphics program shall be provided with a library of standard symbols with the capability for use to add custom symbols or modify library symbols using AutoCadd© version 2000.
 - c. Provide graphics for, but not limited to, the following:
 - (1) Scale floor plans of each level showing status of associated points within area including but not limited to: smoke detectors, HVAC equipment, controls, sensors. Indicate locations of equipment within area such as DDCs, FEPs, MERs, transmitters, actuators, sensors, lighting control panels, etc.
 - (2) Separate air and water systems riser diagrams showing all systems in block diagram form. System status (on, off, alarm) shall be indicated. Risers shall include common sensing points such as outside air and supply and return temperature in main piping systems.
 - (3) Each air and water system.
 - (4) User shall be able to navigate to any graphic from any graphic by clicking 3 or fewer links.
 5. Provide software to output a user programmed message to the printer or video terminal in response to an alarm or change of value of any system point. Message length shall be at least 4 lines of 80 characters each.
 6. All software shall be mouse operated (point and click; drop-and-drag, etc.) with the option of using predefined keyboard commands.

D. Application Software:

1. Time of Day and Event Scheduling:
 - a. Software shall automatically start and stop equipment based on the time of day and day of week, including holidays and the type of event. The scheduled time-of-day program shall operate in conjunction with the

- Start/Stop Time Optimization program.
- b. Schedule assignments shall be for individual points or group of points. For points assigned to one group, assign variable time delays between each successive start or stop command within that group if required. The system shall have the capacity to accommodate a minimum of 500 uniquely defined schedules. Each load group shall accommodate a minimum of 250 loads. Initialize the system with Owner schedules and load assignments.
 - c. The operator shall be able to define the following information:
 - (1) Time, day, dates
 - (2) Commands such as on, off, auto, etc.
 - (3) Load or loads assigned to groups
 - (4) Time delays between successive commands
 - d. Include provisions for manually overriding each schedule.
 - e. The following reports shall be provided:
 - (1) Report of any and all defined time schedules
 - (2) Loads assigned to each time schedule

2. Start/Stop Time Optimization (SSTO):

- a. Software shall perform optimized start-up and shutdown of selected equipment. The SSTO program shall start HVAC equipment at the latest possible time that will allow the equipment to achieve the desired zone conditions by occupancy time. The SSTO program shall also shutdown HVAC equipment at the earliest possible time before the end of the occupancy period, and still maintain desired comfort conditions. Initialize the system with default values used on previous projects of similar construction with similar equipment.
- b. The SSTO program shall operate in both the heating and cooling seasons. It shall be possible to apply the SSTO program to all individual systems.
- c. The SSTO program shall operate on outside weather conditions, as well as inside zone conditions, and empirical factors. The empirical factors shall relate to the dynamic responsiveness of particular zones such as heat retention and transfer coefficients. Provide all needed sensors for effective SSTO implementation. The program shall be fine tuned during the warranty period using empirical data compiled during operation of the building.
- d. The program shall automatically adjust itself utilizing adaptive control techniques.
- e. The system operator shall be able to, for each system under control of the SSTO program, establish and modify the following parameters:
 - (1) Occupancy period
 - (2) Desired occupancy temperature
 - (3) Heating/cooling transfer coefficients
 - (4) Heating/cooling retention coefficients
 - (5) Primary equipment lag time
- f. A report shall be provided detailing SSTO parameters such as zone coefficients, zone occupancy time and temperature, activated/inactivated zones, etc.

3. Demand Limiting:

- a. Software shall perform electrical demand limiting (EDL). The EDL program shall monitor the rate of electrical power consumption and forecast the total demand during each demand interval using a sliding window approach.
- b. The program shall automatically shed and restore loads to prevent the

- electrical demand from exceeding an operator set level.
- c. Kilowatt rating of each load shall be prioritized by the operator to ensure proper number and sequencing of loads being shed when excessive electrical demand is predicted. For initial scheduling purposes, each load shall be assigned to five priority groups.
 - (1) Priority Group 1, 2 and 3: Automatically shed as required.
 - (2) Priority Group 4 and 5: Issue operator advisory to manually shed particular load by operator action at console.
 - d. When load shed condition exists, program begins searching for loads in Group 1 and continues through Group 3 until the necessary number of kilowatts have been shed. Loads within each group shall be shed on an operator selectable basis. Load restoration procedure is opposite of load shedding procedure.
 - e. Each load shall be programmed with maximum off time, minimum on time and minimum off time.
 - f. The operator shall be able to define the following information:
 - (1) Load kilowatt and priority
 - (2) Maximum demand setpoint
 - g. The following information shall be available in report from:
 - (1) Load data
 - (2) Maximum demand for a given period (day, week, month, etc.)
 - (3) Current demand and loads shed
 - h. When an operator-selectable percentage of maximum target is exceeded alarm shall sound, current demand in kilowatt displayed and printed out with time of occurrence on alarm printer.
 - i. Degraded mode: Loss of all or part of data trunk cable shall not cause the shed loads to restart and the electrical load to exceed setpoint. DDCs shall cycle connected loads in a stand-alone mode to eliminate or reduce potential increases in maximum demand level.
4. Automatic Restart: During a power outage the DDC operating programs and database shall be protected against loss of memory with battery backup. If length of the power outage exceeds the battery backup capacity, the programs and database shall be automatically reloaded from disk storage upon power restoration. After power has been restored, the system points shall either be returned to the state they would be in if there were no power outage or remain off as defined by equipment and operational requirements. Points to be restarted shall start over a programmed time schedule to affect soft start.
5. Automatic False Alarm Lockout: When systems are off, certain analog variables may drift past programmed alarm limits. Inhibit analog variable limit alarms until after system is restarted and stabilized.
6. Historical Trending:
- a. Any system point either real or calculated shall be assignable to the historical trending program. All changes in point value shall be recorded for points assigned. The trend interval shall be user selectable. However interval shall initially be 15 minutes or less for analog values.
 - b.
 - c. All trend information shall be recorded in non-volatile memory and graphically displayed. Display shall accommodate up to twelve different point trends simultaneously displayed in user selectable colors and dynamically updated.
 - d. The system shall be configured to store trend data for 12 months or more.

7. Custom Application Program:
 - a. Provide real-time control programming capability to allow operator to create customized control strategies based on arithmetic, logical, conditional, and time logic.

- E. Remote Alarm and Communication Software: The BMS shall alarm and communicate with other off site PC (LOT) by using the modem dial out/in using BACnet Point To Point service or PC Anywhere or equal commercial software. The BMS shall notify the owner via voice or numeric pager of serious alarms on the BMS.

- F. Web Access:
 1. The system shall support at least 64 clients using a standard web browser such as Internet Explorer™ and Remote Desktop. Systems requiring additional software to enable a standard web browser are not acceptable.
 2. The web browser software and Remote Desktop software shall run on any operating system and system configuration that is supported by the web browser.
 3. The web browser and Remote Desktop shall provide the same view of the system, in terms of graphics, schedules, calendars, logs, etc., and provide the same interface methodology as is provided by the Graphical User Interface. Systems that require different views or that require different means of interacting with objects such as schedules, or logs, shall not be permitted.
 4. The web browser and Remote Desktop client shall support at a minimum, the following functions:
 - a. User log-on identification and password shall be required. If an unauthorized user attempts access, a blank web page shall be displayed. Security using authentication and encryption techniques to prevent unauthorized access shall be implemented.
 - b. Graphical screens developed for the GUI shall be the same screens used for the web browser. Any animated graphical objects supported by the GUI shall be supported by the web browser interface.
 - c. HTML programming shall not be required to display system graphics or data on a web page. HTML editing of the web page shall be allowed if the user desires a specific look or format.
 - d. Storage of the graphical screens shall be in the BMS, without requiring any graphics to be stored on the web access computer.
 - e. Real-time values displayed on a web page shall update automatically without requiring a manual "refresh" of the web page.
 - f. User's shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:
 - (1) Modify common application objects, such as schedules, calendars, and set points in a graphical manner.
 - (a) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.
 - (b) Holidays shall be set by using a graphical calendar, without requiring any keyboard entry from the operator.
 - (2) Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No entry of text shall be required.
 - (3) View logs and charts.
 - (4) View and acknowledge alarms.
 - g. Graphic screens on the web browser client and Remote Desktop shall

support hypertext links to other locations on the Internet or on Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

PART 3 – EXECUTION

3.01 LOCATION OF EQUIPMENT

- A. The Drawings and Specifications describe approximate locations of the work. Verify all locations in the field.
- B. Locate equipment and accessories so as to provide easy access for proper service and maintenance.

3.02 INSTALLATION

- A. Provide wiring for control devices, monitoring devices, instrumentation, and interlocks as required for a complete system. Coordinate with Divisions 14, 15, 16 and 17 of the Specifications for devices requiring wiring under this Section.
- B. Run all wiring in compliance with the requirements of the Division 26 Specification and in accordance with authorities and codes having jurisdiction. Provide separate conduit for control wiring under this Section.
- C. Provide all BMS wiring, including power wiring to DDCs and BMS equipment. All power wiring for control system shall be from an emergency power panel.

3.03 EXAMINATION

- A. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the Engineer for resolution before rough-in work is started.
- B. The Contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the Engineer for resolution before rough-in work is started.
- C. The Contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate, or if any discrepancies occur between the plans and the Contractor's work, and the plans and the work of others; the Contractor shall report these discrepancies to the Engineer and shall obtain written instructions for any changes necessary to accommodate the Contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the Contractor to report such discrepancies shall be made by, and at the expense of, this Contractor.

3.04 PROTECTION

- A. The BMS Contractor shall protect all work and material from damage by its work or employees, and shall be liable for all damage thus caused.
- B. The BMS Contractor shall be responsible for its work and equipment until finally inspected, tested, and accepted. The Contractor shall protect any material that is not immediately installed. The Contractor shall close all open of work with temporary covers during storage and construction to prevent entry of foreign objects.

3.05 INSTALLATION OF CONTROL EQUIPMENT

- A. Device and panel locations are the responsibility of the BMS Contractor. Group instrumentation on ductwork, air handling units, packaged equipment and fan casing in an organized manner. Locations shall be consistent for each type of system. Each control device, field or panel mounted, shall be identified by an engraved lamacoid nameplate permanently attached to its enclosure.
- B. Sensors mounted on air ducts having exterior insulation shall be provided with standoff spacers with insulating material firmly fitted around spacers.
- C. Averaging temperature and low temperature detectors shall be installed in serpentine fashion and supported by steel grid or multiple bulb holders. Minimum coverage 1 linear foot of sensor element per 4 square feet of coil face area.
- D. Wall mounted sensors shall be 42 inches above finished floor and consistent with ADA requirements as outlined in Division 1 of the specification. In service corridors where subject to damage, mounting height shall be 84 inches unless noted otherwise. Provide insulated base where mounting on exterior wall is required. Provide metal guards where mounted in mechanical, electrical, storage, and maintenance areas or in any area where subject to damage.
- E. Locate pressure transducers within 50 feet of sensing point. Connect sensors with tubing of diameter recommended by sensor manufacturer and as required to prevent signal phase lag. Provide gauge tees at transducer for connection to pressure gauge.
- F. DDC panels shall not be located directly underneath valves or other areas where they may be subject to water or heat damage. In addition, panels shall be mounted with the bottom no lower than 3 feet and the top no higher than 7 feet above the floor, with a minimum of 3 foot clearance at the front.

3.06 WIRING

- A. All control and interlock wiring shall comply with national and local electrical codes and Division 26 of this specification. Where the requirements of this section differ with those in Division 26, the requirements of this section shall take precedence.
- B. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway per NEC and Division 26 requirements.
- C. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be sub-fused when required to meet Class 2 current-limit.
- D. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations including ceiling return air plenums, approved cables not in raceway may be used, provided that cables are UL listed for the intended application. For example, cables used in ceiling plenums shall be UL listed specifically for that purpose.
- E. All wiring in mechanical, electrical, or service rooms — or where subject to mechanical damage — shall be installed in raceway.
- F. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
- G. Do not install wiring in raceway containing tubing.
- H. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or

perpendicular to it, and neatly tied at 10-foot maximum intervals.

- I. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.
- J. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block in an appropriate enclosure.
- K. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
- L. Maximum allowable voltage for control wiring shall be 120-volt. If only higher voltages are available, the Contractor shall provide step-down transformers.
- M. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
- N. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.
- O. Size of raceway and size and type of wire shall be the responsibility of the Contractor, in keeping with the manufacturer's recommendation and NEC requirements, except as noted elsewhere.
- P. Include one pull string in each raceway 1-inch or larger.
- Q. Use coded conductors throughout with different colored conductors.
- R. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
- S. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 6 inches from high-temperature equipment (over 104 degrees F).
- T. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
- U. Adhere to Division 26 requirements where raceway crosses building expansion joints.
- V. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.
- W. The Contractor shall terminate all control and/or interlock wiring, and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
- X. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 3 feet in length and shall be supported at each end. Flexible metal raceway less than ½ inch electrical trade size shall not be used. In areas exposed to moisture — including chiller and boiler rooms — liquid-tight, flexible metal raceways shall be used.
- Y. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (per code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

3.07 BMS COMMUNICATION WIRING

- A. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.
- B. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.
- C. Maximum pulling, tension, and bend radius for cable installation as specified by the cable manufacturer shall not be exceeded during installation.
- D. Contractor shall verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.
- E. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lightning arrestor shall be installed according to the manufacturer's instructions.
- F. All runs of communication wiring shall be un-spliced length when that length is commercially available.
- G. All communication wiring shall be labeled to indicate origination and destination data.
- H. Grounding of coaxial cable shall be in accordance with NEC Regulations Article on Communications Circuits, Cable and Protector Grounding.

3.08 TRAINING

- A. The Contractor shall furnish the services of competent instructors to give instruction in the adjustment, operation and maintenance, including pertinent safety requirements, of the equipment and system specified. The training shall be oriented toward the system installed rather than being a general training course. Each instructor shall be thoroughly familiar with all aspects of the subject matter they are to teach. The Contractor shall provide all equipment and material required for classroom training.
- B. The training program shall be accomplished in two phases for the time interval specified for each phase.
 - 1. The first phase shall be given prior to the acceptance test period at a time mutually agreeable between the Contractor and the Owner, and shall be at least five (5) days (8 hours/day) in length. Operating personnel shall be trained in the functional operations of the BMS installed and the procedures that the operators will employ for system operation. The training shall include but not be limited to:
 - a. General BMS configuration
 - b. Operation of computer and peripherals
 - c. Command line mnemonics
 - d. Report generation
 - e. Operator control functions
 - f. Graphics generation
 - g. General equipment layout
 - h. Troubleshooting procedures
 - i. Preventative maintenance procedures
 - j. Sensor maintenance and calibration
 - k. Proper use of service kit
 - 2. The second phase shall be conducted after system acceptance testing for a period of eight (8) days. The training shall occur up to one year after the first phase of training as determined by the Owner and shall include but not be limited to:

- a. DDC programming
- b. Database generation
- c. Supervisory level operator commands
- d. Topics requested by Owner

3.09 CALIBRATION AND COMMISSIONING

- A. Perform a three-phase commissioning procedure consisting of field I/O calibration and commissioning, system commissioning and integrated system program commissioning. Document all commissioning information on commissioning data sheets that shall be submitted prior to acceptance testing. Notify the Owner in writing of the testing schedule so that operating personnel may observe calibration and commissioning.
- B. Field I/O Calibration and Commissioning:
 - 1. Prior to system program commissioning, verify that each control panel has been installed according to the shop drawings and test, calibrate, and bring on-line each control device. Commissioning to include but not be limited to:
 - a. Sensor accuracy at 10, 50 and 90 percent of range
 - b. Sensor range
 - c. Verify analog limit and binary alarm reporting
 - d. Point value reporting
 - e. Binary alarm and switch settings
 - f. Actuator spring ranges
 - g. Failsafe position on loss of control signal
 - 2. Record calibration and test data on commissioning data sheets and submit. Data sheets shall include the device designation, the date of commissioning and the name of person who performed commissioning.
- C. System Program Commissioning: After control devices have been commissioned, each DDC program shall be put on-line and commissioned. The Contractor shall confirm that the DDC program logic follows the approved software flow chart and sequence of operation. Each control loop shall be adjusted to provide stable control and control within the specified accuracies. System program test results and loop adjustments shall be recorded on commissioning data sheets and submitted.
- D. Integrated System Commissioning:
 - 1. After all DDC programs have been commissioned, the Contractor shall verify the overall system performs as specified. Tests shall include but not be limited to:
 - a. Data communication, both normal and failure modes
 - b. Fully loaded system response time
 - c. Impact of component failures on system operation
 - d. Time/date changes
 - e. End of month/end of year operation
 - f. Global application programs
 - g. System backup and reloading
 - h. System status displays
 - i. Diagnostics
 - j. Power fail/restart
 - k. Battery backup

3.10 ACCEPTANCE TESTING

- A. Submit a detailed acceptance test procedure designed to demonstrate compliance with contract requirements at least 4 weeks before the start of testing. This procedure to be

approved prior to the start of the testing.

- B. During acceptance testing provide services of a fully qualified building automation technician who is knowledgeable of the project.
- C. Using the commissioning test data the Owner shall select, at random, functions to be demonstrated. The Contractor in accordance with the acceptance test procedure shall demonstrate these functions. At least 15 percent of the systems functions shall be demonstrated. At least 95 percent of the functions demonstrated must perform as specified and documented on commissioning data sheets or the system must be retested.
- D. Furnish instruments required for testing. Submit catalog data on all instruments for approval prior to performance tests.

| Instrument Accuracy | |
|---------------------|---|
| Temperature: | ¼ degree F or ½ percent of full scale, whichever is less |
| Pressure: | ½ pound per square inch or ½ percent of full scale, whichever is less |
| Humidity: | ½ percent relative humidity |
| Electrical: | ¼ percent of full scale |

- E. After the above acceptance tests are complete and the system is demonstrated to be functioning as specified, a thirty-day endurance test period shall begin. If the system functions as specified throughout the endurance test period requiring only routine maintenance and adjustment, the system shall be accepted. If during the endurance test period the system fails to perform as specified and cannot be corrected within eight hours, the Owner may request that the endurance tests be repeated after problems have been corrected.

END OF SECTION

SECTION 23 09 65

LABORATORY AIRFLOR CONTROL SYSTEM

PART 1 – GENERAL

1.01 RELATED SECTIONS

- A. Section 23 05 01 - Mechanical General Provisions
- B. Section 23 09 00 - Building Management System
- C. Section 23 36 00 - Air Terminal Devices
- D. Division 26 - Electrical Specifications

1.02 DESCRIPTION OF WORK

- A. Laboratory airflow control system shall be furnished and installed to control the airflow into and out of laboratory rooms. The exhaust volume of a laboratory fume hood shall be precisely controlled to maintain a constant average face velocity into the fume hood. The laboratory control unit shall vary the amount of air into the room to maintain temperature control, minimum ventilation, airflow balance, and laboratory pressurization in relation to adjacent spaces (positive or negative).

1.03 SUBMITTALS

- A. Submit manufacturer's certified airflow performance test data, sound performance test data, and certified dimensioned drawings.
- B. Submit materials of construction, assembly details, wiring details, and mounting details.

1.04 MANUFACTURERS

- A. Phoenix Controls.
- B. TSI (Note: TSI lab system shall be based on their own system with hardware and other controls as required for a complete laboratory ventilation system with equal or better performance to these specifications.)

1.05 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

- A. Designated circuits shall be furnished by the Division 26 Contractor from the distribution panelboards for BMS power. Power wiring from the designated power outlets or circuits shown on Division 26 drawings to BMS components shall be within the work scope of this section.

PART 2 – PRODUCTS

2.01 PHOENIX LABORATORY AIRFLOW CONTROL SYSTEM

- A. The laboratory airflow control system shall be fully stand-alone for each individual control zone. The system shall not use or rely on information from controllers in other laboratory areas to control the functions within its laboratory.
- B. The laboratory airflow control system shall directly measure the area of the fume hood

sash opening and proportionally control the hood's exhaust airflow in a variable volume mode to maintain a constant face velocity over a minimum range of 20 to 100% at full sash opening. System shall be capable of minimum change in hood exhaust flow of 5 to 1. Response time shall be less than one second with no more than a 5% overshoot or undershoot. The system shall achieve 90% of its commanded volume within one second of the sash reaching 90% of its final value with a full height sash movement of one second.

- C. The laboratory airflow control system shall respond and maintain specific airflow ($\pm 5\%$ of signal) and stability ($< 5\%$ over/undershoot) within one second of a change in duct static pressure irrespective of the magnitude of pressure and/or flow change or quantity of airflow controllers on a manifolded system.
- D. The laboratory airflow control system shall also maintain intersystem stability within one second of a change in pressure and/or flow to eliminate hunting, system oscillations, and crosstalk between airflow controllers.
- E. The laboratory airflow control system shall use volumetric offset control to maintain room pressurization. The system shall respond and maintain room pressurization (negative or positive) within one second of a change in room/system conditions.
- F. The laboratory airflow control system shall employ highly accurate airflow controllers ($\pm 5\%$ of signal) with a minimum 10 to 1 turndown.

2.02 FACE VELOCITY CONTROLLER

- A. A vertical sash sensor shall be provided to measure the height of each vertically moving fume hood sash. A horizontal sash sensor shall be provided for each pair of horizontal or overlapping sashes that are located on horizontal, combination, California, walk-in, or distillation type fume hoods.
- B. The airflow at the fume hood shall vary in a linear manner between two adjustable minimum and maximum flow setpoints to maintain a constant face velocity throughout this range. A minimum volume shall be set to insure flow through the fume hood even with the sash totally closed.
- C. A fume hood monitor shall be provided to receive the sash sensor output signal and to generate an exhaust airflow control signal for the appropriate volume control device in order to provide a constant face velocity. Audible and separate visual alarms shall be provided for both flow alarm and emergency exhaust conditions.

2.03 AIRFLOW CONTROLLER - GENERAL

- A. The airflow controller shall be of the Phoenix Controls Accel II Venturi Valve control type or equivalent. The valve shall be manufactured and assembled in the United States, including all materials.
- B. The valve shall be pressure independent over a 0.6" to 3.0" W.C. drop across the valve. Integral pressure independent assembly shall respond and maintain specific airflow within one second of a change in duct static pressure irrespective of the magnitude of pressure and/or flow change or quantity of airflow controllers on a manifolded system.
- C. Airflow accuracy shall be $\pm 5\%$ of reading (not full scale) over an airflow turndown range of no less than 8 to 1. No minimum entrance or exit duct diameters shall be required to ensure speed of response, accuracy, or pressure independence.
- D. The valve shall be constructed of one of the following two types:

1. Supply and general exhaust air assembly shall be constructed of 16 gauge aluminum. All bearing surfaces shall be made of a composite teflon or teflon infused (versus coated) aluminum. The assembly's shaft, pivot arm, shaft support brackets, and internal mounting hardware shall be made of 316 series stainless steel. Lesser grade stainless steel materials are unacceptable.
 2. Fume hood, canopy, snorkel, and biosafety cabinet exhaust assemblies shall have two baked-on coats of a corrosion resistant phenolic coating (Heresite P403 or Phenoflex 957 or equal). The assembly's shaft shall be 316L stainless steel with two additional baked-on coats of a corrosion resistant phenolic coating. The pivot arm, shaft support brackets, and internal mounting hardware shall be made of 316L stainless steel. All bearing surfaces shall be made of a composite teflon or teflon infused (versus coated) aluminum.
- E. An electric actuator shall be factory mounted to the valve. Loss of power shall cause the valves to fail in the following positions:
1. Fume hood exhaust valves: fail open.
 2. General exhaust valves:
 - a. Fume hood control zone: fail closed.
 - b. Non-fume hood control zone: fail open.
 3. Supply valves: fail open.
- F. Airflow controllers that use VAV boxes or control dampers shall not be acceptable.
- G. Certification:
1. Each airflow control valve assembly shall be factory calibrated to the job specific airflows as detailed on the plans and specifications using NIST traceable air stations and instrumentation having a combined accuracy of at least $\pm 1\%$ of signal over the entire range of measurement. Electronic valves shall be further calibrated and their accuracy verified to $\pm 5\%$ of signal at eight different airflows per valve.
 2. All airflow valves shall be individually marked with valve specific, factory calibration data. As a minimum, it shall include: valve tag number, serial number, model number, eight point valve characterization information (electronic valves), and quality control inspection numbers. All information shall be stored on computer diskette in ASCII format for future retrieval or for hard copy printout to be included with as-built documentation.
- H. Airflow Control Sound Specifications:
1. Unless otherwise specified, the airflow control device shall not exceed the sound power levels in Table 1, Table 2 and Table 3.
 2. If the airflow control device cannot meet the sound power level specification, a properly sized silencer or sound attenuator must be used. All silencers must be of a packless design (constructed of at least 18 gauge 316L stainless steel when used with fume hood exhaust) with a maximum pressure drop at the device's maximum 0.3 inches of water.
 3. All proposed airflow control devices shall include discharge, exhaust and radiated sound power level performance.

Table 1. Exhaust Airflow Control Device Sound Power Level

| Octave Band Number | Exhaust Sound Power Level in dB (re: 10^{-12} watts) | | | | | |
|------------------------|--|--------|--------|---------|---------|---------|
| | 2 | 3 | 4 | 5 | 6 | 7 |
| Center Frequency in Hz | 125 Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz |

| | | | | | | |
|---|----|----|----|----|----|----|
| 1000-50 cfm Device | 63 | 55 | 52 | 54 | 50 | 49 |
| 800 cfm @ 0.6" wc 200 cfm @ 0.6" wc 800 cfm @ 3.0" wc 200 cfm @ 3.0" wc | 46 | 42 | 38 | 37 | 32 | 25 |
| 1500-100 cfm Device | 65 | 58 | 53 | 56 | 52 | 52 |
| 1200 cfm @ 0.6" wc 400 cfm @ 0.6" wc 1200 cfm @ 3.0" wc 400 cfm @ 3.0" wc | 50 | 45 | 38 | 39 | 37 | 31 |
| 1000-50 cfm Device | 63 | 56 | 55 | 58 | 54 | 55 |
| 800 cfm @ 0.6" wc 200 cfm @ 0.6" wc 800 cfm @ 3.0" wc 200 cfm @ 3.0" wc | 51 | 45 | 41 | 42 | 39 | 34 |
| | 75 | 71 | 65 | 68 | 67 | 63 |
| | 58 | 58 | 56 | 56 | 59 | 58 |

Table 2. Supply Airflow Control Device Sound Power Level (Discharge)

| Octave Band Number | Discharge Sound Power Level in dB (re: 10 ⁻¹² watts) | | | | | |
|---|---|--------|--------|---------|---------|---------|
| | 2 | 3 | 4 | 5 | 6 | 7 |
| Center Frequency in Hz | 125 Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz |
| 1000-50 cfm Device | 62 | 57 | 54 | 58 | 54 | 51 |
| 800 cfm @ 0.6" wc 200 cfm @ 0.6" wc 800 cfm @ 3.0" wc 200 cfm @ 3.0" wc | 45 | 46 | 42 | 44 | 40 | 34 |
| | 72 | 71 | 67 | 75 | 72 | 68 |
| | 53 | 56 | 54 | 58 | 56 | 54 |
| 1500-100 cfm Device | 63 | 59 | 55 | 60 | 54 | 53 |
| 1200 cfm @ 0.6" wc 400 cfm @ 0.6" wc 1200 cfm @ 3.0" wc 400 cfm @ 3.0" wc | 53 | 49 | 44 | 49 | 45 | 39 |
| | 72 | 73 | 69 | 77 | 72 | 68 |
| | 58 | 63 | 61 | 63 | 60 | 57 |
| 3000-200 cfm Device | 64 | 60 | 58 | 63 | 56 | 56 |
| 2400 cfm @ 0.6" wc 800 cfm @ 0.6" wc 2400 cfm @ 3.0" wc 800 cfm @ 3.0" wc | 52 | 48 | 47 | 52 | 46 | 41 |
| | 75 | 75 | 72 | 78 | 73 | 70 |
| | 59 | 62 | 62 | 66 | 62 | 60 |

Table 3. Supply Airflow Control Device Sound Power Level (Radiated)

| Octave Band Number | Radiated Sound Power Level in dB (re: 10 ⁻¹² watts) | | | | | |
|---|--|--------|--------|---------|---------|---------|
| | 2 | 3 | 4 | 5 | 6 | 7 |
| Center Frequency in Hz | 125 Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz |
| 1000-50 cfm Device | 44 | 41 | 45 | 41 | 36 | 34 |
| 800 cfm @ 0.6" wc 200 cfm @ 0.6" wc 800 cfm @ 3.0" wc 200 cfm @ 3.0" wc | 33 | 28 | 31 | 29 | 26 | 20 |
| | 53 | 53 | 56 | 57 | 55 | 53 |
| | 41 | 38 | 41 | 39 | 39 | 37 |
| 1500-100 cfm Device | 47 | 53 | 40 | 42 | 38 | 36 |
| 1200 cfm @ 0.6" wc 400 cfm @ 0.6" wc 1200 cfm @ 3.0" wc 400 cfm @ 3.0" wc | 35 | 39 | 31 | 34 | 33 | 26 |
| | 52 | 60 | 54 | 60 | 59 | 53 |
| | 42 | 44 | 43 | 46 | 46 | 42 |
| 3000-200 cfm Device | 58 | 56 | 45 | 47 | 43 | 42 |
| 2400 cfm @ 0.6" wc 800 cfm @ 0.6" wc 2400 cfm @ 3.0" wc 800 cfm @ 3.0" wc | 45 | 43 | 36 | 39 | 37 | 29 |
| | 69 | 68 | 60 | 65 | 63 | 57 |
| | 54 | 53 | 48 | 51 | 50 | 48 |

2.04 EXHAUST AND SUPPLY AIRFLOW CONTROLLER

- A. The controller shall use electronic-based, closed loop control to regulate air volume linearly proportional to a 0 to 10 volt electronic control signal. The valve shall generate a 0 to 10 volt feedback signal linearly proportional to its airflow for internal volume control, DDC monitoring, or airflow tracking control.

2.05 CONSTANT VOLUME VALVE

- A. The valve shall maintain a constant, manually adjustable, volume setpoint. It shall be factory calibrated and set for desired airflow rate. It shall also be capable of field adjustment for future changes of desired airflow rate. Constant volume valves requiring feedback shall generate a 0 to 10 volt feedback signal linearly proportional to its airflow for DDC monitoring or airflow tracking control.

2.06 LABORATORY CONTROL UNIT

- A. A laboratory control unit shall be supplied to control the airflow balance of the laboratory room. As a minimum, provide one complete, stand-alone laboratory control unit per fume hood control zone.
- B. The control unit shall be of electronic design with analog signal inputs and outputs. The inputs shall accept signals proportional to control zone supply flows. The output signals shall control supply valves and general exhaust/return air valves with signals linearly proportional to the desired supply or exhaust volumes.
- C. The control unit shall maintain a constant, adjustable offset between the sum of the room's total exhaust and the make-up/supply air volumes. This offset shall be independent of the exhaust volume magnitude.
- D. The control unit shall generate analog signals linearly proportional to all airflow sources, sash sensors, and flow alarms. The signals shall be available for connection to the facility's direct digital control (DDC) system through an integrated control unit that interfaces directly into the facility's DDC system. As a minimum, the following signals (points) shall be available:
 - 1. Fume hood exhaust flow
 - 2. Fume hood exhaust low flow alarm
 - 3. Fume hood sash position
 - 4. Fume hood usage status
 - 5. Supply/make-up airflow
 - 6. General exhaust flow
 - 7. Total lab exhaust flow
 - 8. Total lab supply flow
 - 9. Room offset
- E. The control unit shall also accept direct input signals from the facility's DDC or be carried out by an integrated DDC control unit. As a minimum, the following inputs shall be available:
 - 1. Emergency exhaust override
 - 2. Remote room offset adjustment
 - 3. Electronic temperature override
 - 4. Minimum air volume reset (based on unoccupied signal from the Building Management System)
- F. An integral or wall-mounted power supply shall be included to power the complete laboratory airflow control system from 120 VAC standby power circuit dedicated to control power. On loss of power, valves shall fail to the positions described in paragraph 2.03.E.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. The contractor shall install the sash sensors, interface boxes, and the monitor on the fume hood. Vertical sash sensors and their stainless steel cables shall be hidden from view. Horizontal sash sensor bars shall be affixed to the individual sash panels. Sash interface boxes with interface cards shall be mounted within an accessible location. Refer to laboratory casework details for types of sashes.
- B. The contractor shall install the laboratory control unit (if panel mounted) and wall-mounted power supply (as required) in an accessible location within the indicated laboratory room. The contractor shall furnish single phase 120 VAC power circuit to the laboratory control unit or wall-mounted power supply from the Division 26 designated circuit.
- C. The contractor shall terminate and connect all cables as required. All cable and connectors shall be furnished by the Contractor.
- D. Linearized airflow control valves shall be installed in the duct work by Division 15. All reheat coils, transitions, and insulation shall be furnished and installed by Division 15.

3.02 SYSTEM START-UP AND TRAINING

- A. System start-up shall be provided by a factory authorized representative of the laboratory airflow controls manufacturer. Said start-up shall include setting of the fume hood face velocity and electronic verification of supply, make-up, general exhaust, and return airflows. The contractor shall be responsible for final verification and reporting of all airflows.
- B. The laboratory airflow control system manufacturer shall furnish a minimum of sixteen hours of on-site training to provide an overview of the job specific airflow control components, calibration procedures in resetting fume hood velocities, general procedures for verifying airflows of air valves, and general troubleshooting procedures.

END OF SECTION

SECTION 23 09 93

AUTOMATIC CONTROL SEQUENCES

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Supply and install necessary software, programming, sensing, controlling and controlled devices, piping, wiring and commissioning of automatic control systems, so as to provide a complete control system, meet requirements of control sequences specified.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

3.01 GENERAL

- A. Contractor shall provide customized control strategies and control sequences and define appropriate control loop algorithms and choose the optimum loop parameters for loop control. All control loops shall be tuned to stabilize within plus or minus 1 percent of setpoint within 5 minutes of setpoint change or startup.
- B. Safety devices shall be hardwire interlocked with “hand” and “automatic” positions in series with motor controller holding circuit.
- C. Smoke control, fire and life safety sequences shall override other automatic control sequences including hardwired safety devices.
- D. Reset schedules and setpoints shown in sequences are for initial programming and start up. During system commissioning the reset schedules and setpoints shall be fine tuned to obtain desired thermal comfort, energy and ventilation system results.
- E. The intent of the reset schedules indicated is that the range of the output be limited between the minimum and maximum values indicated in the reset schedules.
- F. All functions which use analog points to switch equipment on and off (e.g., fans, pumps) must be programmed with dead bands, and if necessary, time delays to prevent short cycling of equipment.
- G. Starting of fans and pumps shall have built in time delays where a damper or valve is required to open or close prior to fan or pump pressure build up.
- H. The scale for all valves and dampers shall be from 0-100% as shown in the graphics workstation. Showing the signal in PSI or volts shall not be permitted. 0% shall represent valve fully closed to coil, heat exchanger, etc. 100% shall represent valve fully open to coil, heat exchanger, etc. 0% shall represent full closed damper and 100% shall represent fully open dampers.

3.02 SEQUENCE OF OPERATION

A. Modes of Operation Definition:

1. Occupied Mode:

- a. The system shall operate in occupied mode whenever the schedule indicates an occupied time period or when any zone control space temperature sensor override device is in the override position or;
- b. The warm-up or cool down cycle is complete but the scheduled occupancy period start time has not been reached.

2. Warm Up Mode:

- a. The BMS shall calculate a representative zone temperature based on the average of selected zone temperatures.
- b. An optimal start program shall determine the required start time to bring the building's representative space temperature to its occupied heating setpoint by the scheduled occupancy period.
- c. Warm-up mode shall be initiated if:
 - (1) The optimal start program determines that morning warm-up is required and the building is in unoccupied mode at the optimal start time.
- d. Warm Up mode shall end when:
 - (1) the representative zone temperature reaches setpoint, or
 - (2) return air temperature rises above 68 degrees F, or
 - (3) a scheduled occupancy period has started, or
 - (4) the building enters after-hours override occupied mode.
- e. Upon ending warm-up mode, the building shall enter occupied mode.

3. Cool Down Mode:

- a. The BMS shall calculate a representative zone temperature based on the average of selected zone temperatures.
- b. An optimal start program shall determine the required start time to bring the building's representative space temperature to its occupied cooling setpoint by the scheduled occupancy period.
- c. Cool down mode shall be initiated if:
 - (1) the optimal start program determines that cool down is required and the building is in unoccupied mode at the optimal start time.
- d. Cool down mode shall end when:
 - (1) the representative zone temperature reaches setpoint, or
 - (2) return air temperature drops below 76 degrees F, or
 - (3) a scheduled occupancy period has started, or
 - (4) the building enters after-hours override occupied mode.
- e. Upon ending cool down mode, the building shall enter occupied mode.

4. Unoccupied Mode:

- a. The building is considered to be in unoccupied operation whenever it is not

- in warm-up, cool down or occupied operation.
 - b. The system shall not operate whenever the operating schedule indicates an unoccupied time period.
- 5. Fire Mode:
 - a. The system shall run in this mode based on input from the fire alarm system. This mode shall have priority over all other control modes.

3.03 LABORATORY HEAT RECOVERY VENTILATOR – 100% OUTSIDE AIR

- A. General:
 - 1. HRV-1, HRV-2
- B. System Off:
 - 1. Supply fan wall system is off.
 - 2. Outdoor air damper closed.
 - 3. Supply air damper closed.
 - 4. The heating coil control valve shall be under control of its discharge temperature control loop.
 - 5. Control loops inactive.
- C. System Start:
 - 1. Operator entered command at the BMS.
 - 2. Automatically by the BMS based on preprogrammed schedule.
- D. Occupied Mode:
 - 1. Both HRV-1 and HRV-2 shall operate simultaneously.
 - 2. Prior to starting the supply fan wall system the outside air dampers, and supply air dampers shall open fully as proven by the damper end switches. Start supply fans. Report fan status at the BMS.
 - 3. The heating valve, the evaporative cooling system, and the cooling valve shall operate in sequence without overlap to maintain lowest setpoint between the discharge air setpoint and the dehumidification discharge air setpoint.
 - 4. The BMS shall indicate on the graphics when the dehumidification setpoint is being utilized.
 - 5. The discharge air setpoint shall reset based on outdoor air temperature.
 - 6. The dehumidification supply air setpoint shall modulate between 65 and 50 degrees to maintain the return air relative humidity at 50%.
 - 7. Indirect Evaporative Cooling
 - a. The evaporative cooling system shall be the first stage of cooling. The spray pump shall start and the spray valve shall open during a cooling call. The chilled water valve shall operate as a secondary stage of cooling.
 - b. If the outdoor air temperature is less than 35 degrees F, the spray system shall be disabled. The spray valve shall close and the drain valve shall open.
 - c. If the outdoor air temperature is above 40 degrees F, the spray system shall be enabled. The drain valve shall close.
 - 8. Heat Pipe / Face and Bypass Damper
 - a. The face and bypass dampers shall be physically linked or the actuators shall operate in unison such that the face dampers move in opposition to the bypass dampers.

- b. The face and bypass dampers shall modulate to maintain the pre-coil temperature at the supply air temperature setpoint as follows:
 - (1) If the pre-coil air temperature is 2 degrees less than the outside air temperature the heat pipe shall be assumed to be operating in cooling mode.
 - (a) If the pre-coil temperature rises above the supply air temperature setpoint, the face and bypass damper shall bypass less air around the coil.
 - (b) If the pre-coil temperature drops below the supply air temperature setpoint, the face and bypass damper shall bypass more air around the coil.
 - (2) If the pre-coil air temperature is 2 degrees greater than the outside air temperature the heat pipe shall be assumed to be operating in heating mode.
 - (a) If the outdoor air temperature is above 38 degrees:
 - (i) If the pre-coil temperature rises above the supply air temperature setpoint, the face and bypass damper shall bypass more air around the coil.
 - (ii) If the pre-coil temperature drops below the supply air temperature setpoint, the face and bypass damper shall bypass less air around the coil.
 - (b) If the outdoor air temperature is below 32 degrees:
 - (i) The face and bypass dampers shall modulate to maintain an exhaust air temperature at 36 degrees.

9. Fan Speed Control

- a. Both supply fans shall operate to a common speed reference.
- b. When the supply fan wall systems start, the supply pressure setpoint shall ramp from 0 inwc to the final pressure setpoint over a period of 2 minutes. The supply fan speed reference shall modulate to maintain the temporary setpoint during the ramp up period.
- c. The supply fan speed reference shall modulate based in the lowest supply air static reading among HRV-1 and HRV-2 supply static pressure sensors and increasing or decreasing fan speed to maintain airflow setpoint.

E. Unoccupied mode

- 1. If the fan speed reference is below 40% for more than 10 minutes, the lag HRV shall stop.
 - a. The lag HRV supply fan shall ramp down to minimum speed over a 2 minute period.
 - b. After the ramp down period, the lag HRV shall turn off.
 - c. After the supply fan has proven off, close supply, and outside air dampers.
- 2. The lead HRV shall continue to operate based on the Occupied sequence.
- 3. If the supply static pressure is 0.5 inwc below setpoint for more than 1 minute or the lead HRV is operating above 95% for more than 5 minutes, the lag HRV shall start and operate in occupied mode until the next unoccupied mode.
- 4. The lead / lag designation shall rotate weekly.

- a. The HRV with the supply fan with the greatest runtime shall be designated as the lag unit during the next Unoccupied mode.
- 5. If the lead HRV fails or alarms, then the lead/lag order shall switch and an alarm shall be generated.
- F. System Stop:
 - 1. Operator command at the BMS or automatically by the BMS based on a preprogrammed schedule.
 - 2. When the system is called to stop, the system shall revert to that "Off" state as described above.
- G. Setpoints:
 - 1. Supply air temperature between reset linearly as flows:
 - a. When the Outdoor Air Temperature is 45 degrees F or below, the supply air setpoint shall be 65 degrees F.
 - b. When the Outdoor Air Temperature is 80 degrees F or above, the supply air setpoint shall be 55 degrees F.
 - 2. Duct static pressure setpoint shall be determined by balancer.
- H. Alarms:
 - 1. Alarm at BMS at +/- 2 degrees F from setpoint.
 - 2. Alarm at BMS at +/- .50-inch w.g from setpoint.
- I. Safeties:
 - 1. A freezestat with its element serpentine across the discharge side of the heating coil shall stop the supply fans, close the outside air damper, open the heating coil valve fully and alarm the BMS. Freezestat shall be the automatic reset type. Whenever the alarm is actuated, the point will be held by the BMS until manually released by the BMS operator.
 - 2. A high static safety switch shall stop the supply fan wall system in the static pressure exceeds 3.5 inwc. The BMS shall generate an alarm.
 - 3. A differential pressure sensor installed across both filter banks shall indicate whenever the filter is obstructed and initiate a non-critical alarm at the BMS.
 - 4. The BMS shall monitor the status of each fan with a currently sensing relay. If one or more fans fail, an alarm shall be generated.
 - 5. The BMS shall also monitor the status of the entire fan wall system with a differential pressure switch.
 - 6. If the fan wall is called to run and the and the pressure and current sensors both confirm the fans are not operating, the fans shall be disabled, the dampers shall be closed and an alarm shall be generated.

3.04 OFFICE AREA VARIABLE VOLUME AIR CONDITIONING SYSTEMS

- A. General:
 - 1. RTU-3, RTU-4, RTU-5
- B. System Off:
 - 1. Minimum outside air, economizer outside and relief air dampers closed.
 - 2. Supply damper shall close. (RTU-4 and RTU-5 only)

3. Return air damper open.
4. Supply fan and return fan off.
5. Chilled water control valve closed.
6. The heating coil control valve will be under control of its discharge temperature control loop.
7. All other control loops inactive.

C. System Start:

1. Operator entered command at the BMS.
2. Automatically by the BMS based on preprogrammed schedule.

D. System Operation:

1. The supply damper shall open (RTU-4 and RTU-5 only)
2. After the supply damper is verified open by end switch (RTU-4 and RTU-5 only) the supply fan shall start.
3. Fan Speed Control
 - a. When the supply fan wall system starts, the supply static pressure setpoint shall ramp from 0 inwc to the final setpoint over a period of 2 minutes. The supply fans speed shall modulate to maintain the temporary setpoint during the ramp up period.
 - b. Supply fan speed shall modulate by sensing supply duct static pressure and increasing or decreasing fan speed to maintain static pressure setpoint.
 - c. The return fan speed shall modulate to maintain the return air flow setpoint.
 - d. The return air flow setpoint shall be:

$$(1) \quad \text{Return airflow setpt} = \text{Supply Airflow} - \text{Min OSA Setpt} - \text{Offset}$$

4. Building Pressure Control:

- a. If building static pressure is .01 inwc above setpoint for more than 1 minute, the fan offset CFM shall increase by 200 CFM every minute.
- b. If building static pressure is .01 inwc below setpoint for more than 1 minute, the fan offset CFM shall decrease by 200 CFM every minute.
- c. The offset set shall not be greater than +/- 30% of design supply airflow.

5. Cool Down Mode:

- a. During the cool down mode, the dampers shall be controlled as described in the occupied mode. Minimum outside airflow setpoint shall be zero.
- b. During the transition from non-economizer mode to economizer mode the economizer dampers shall ramp open slowly over a 5 minute period.
- c. The cooling valve shall be modulated to maintain a discharge temperature of 55 degrees F.

6. Occupied Mode:

- a. The minimum outside air damper shall modulate to minimum airflow setpoint.
- b. If outside air temperature is 2 degrees less than the return air temperature, the dampers shall modulate as required to maintain the discharge air temperature setpoint.
- c. If outside air temperature is greater than the return air temperature, the economizer dampers shall be closed to minimum position.
- d. Minimum damper positions shall be determined as follows.

$$(1) \quad \text{EAD/RAD min pos} = -\text{Offset} / \text{Supply Air Flow}$$

(2) OSA min pos = Offset / Supply Air Flow

- e. During the transition from non-economizer mode to economizer mode the economizer dampers shall ramp open slowly over a 5 minute period.
- f. The heating valve, economizer dampers and cooling valve shall operate in sequence without overlap to maintain lowest setpoint between the discharge air setpoint and the dehumidification discharge air setpoint.
- g. The BMS shall indicate on the graphics when the dehumidification setpoint is being utilized
- h. The discharge air setpoint shall reset based on outdoor air temperature.
- i. The dehumidification supply air setpoint shall modulate between 65 and 45 degrees to maintain the return air relative humidity at 50%.

7. Building CO2 sequence

- a. The BMS shall calculate the CO2 differential between the indoor and outdoor air.
- b. If the CO2 differential is less than 300 PPM for 5 minutes or the hot water valve is 100% open, then the minimum outside airflow setpoint shall decrease by 400 CFM every 5 minutes. The minimum outside airflow shall not be allowed to reset below the minimum outside airflow CFM. (See equipment schedule)
- c. If the CO2 differential is greater than 500 PPM for 5 minutes and the hot water valve is less than 90% open, then the outside airflow minimum shall increase by 800 CFM every 5 minutes. The outside airflow setpoint shall not be allowed to reset fan design CFM.

E. System Stop:

- 1. Operator command at the BMS or automatically by the BMS based on a preprogrammed schedule.
- 2. When the system is called to stop, the system shall revert to that "Off" state as described above.

F. Setpoints:

- 1. Supply air temperature between reset linearly as flows:
 - a. When the Outdoor Air Temperature is 45 degrees F or below, the supply air setpoint shall be 65 degrees F.
 - b. When the Outdoor Air Temperature is 80 degrees F or above, the supply air setpoint shall be 55 degrees F.
- 2. The BMS shall determine the number of boxes with 100% open primary air dampers.
 - a. If 10% (adj.) or more of boxes have dampers that are 100% open, then the supply duct static pressure setpoint shall increase by 0.1 inwc every 5 minutes.
 - b. If 5% (adj.) or fewer boxes have dampers that are 100% open, then the supply duct static air pressure setpoint shall decrease by 0.1 inwc every 5 minutes.
 - c. The duct static pressure setpoint shall not be reset below 0.75 inwc and above 1.75 inwc limits (adj.).

G. Alarms:

- a. Alarm at BMS at Supply Air Temperature +/- 2 degrees F from setpoint.
- b. Alarm at BMS at Supply Static Pressure +/- .50-inch w.g from setpoint.

H. Safeties:

1. A differential pressure sensor installed across the filter shall indicate whenever the filter is obstructed and initiate a non-critical alarm at the BMS.
2. A high static safety switch shall stop the supply fan wall system in the static pressure exceeds 3.5 inwc. The BMS shall generate an alarm.
3. A freezestat with its element serpentine across the discharge side of the heating coil shall stop the supply fans, close the outside air damper, open the heating coil valve fully and alarm the BMS. Freezestat shall be the automatic reset type. Whenever the alarm is actuated, the point will be held by the BMS until manually released by the BMS operator.
4. (RTU-4 and RTU-5 only) If the supply fan fails, the supply fan damper shall close and the BMS shall generate an alarm.

3.05 LABORATORIES

A. Setpoints

1. Occupied cooling setpoint shall be 76 degrees F
2. Occupied heating setpoint shall be 70 degrees F
3. Unoccupied cooling setpoint shall be 82 degrees F
4. Unoccupied heating setpoint shall be 65 degrees F

B. Night override.

1. The system shall revert back to Occupied setpoints for a period of 2 hours each time the night override mode button is depressed by an occupant.

3.06 LABORATORIES (NEGATIVE PRESSURE)- GENERAL APPROACH TO SEQUENCES

- A. The supply air temperature setpoint shall modulate to maintain the space temperature at heating setpoint.
- B. The heating valve shall modulate to maintain the supply air temperature setpoint.
- C. On a call for cooling, the BMS shall modulate the total exhaust airflow setpoint from minimum to maximum airflow as required to maintain the cooling temperature setpoint. Minimum exhaust airflow setpoint shall be equal to the ventilation requirement plus the scheduled room offset. The general exhaust shall modulate to maintain the total exhaust airflow setpoint minus the airflow of the fume hood exhaust and bio safety cabinets.
- D. The BMS shall calculate the total airflow of the room exhaust and calculate the required supply airflow setpoint by subtracting the scheduled room offset. The offset shall be adjustable from the BMS Graphical Interface.

3.07 LABORATORIES (POSITIVE PRESSURE)- GENERAL APPROACH TO SEQUENCES

- A. The supply air temperature setpoint shall modulate to maintain the space temperature at heating setpoint.
- B. The heating valve shall modulate to maintain the supply air temperature setpoint.
- C. On a call for cooling, the BMS shall modulate the supply airflow setpoint from minimum to maximum airflow as required to maintain space temperature cooling setpoint. Minimum supply airflow setpoint shall be equal to the ventilation requirement. The supply air flow shall modulate to maintain the supply airflow setpoint.
- D. The BMS shall calculate the supply air flow of the room and calculate the total exhaust flow setpoint by subtracting the scheduled room offset. The general exhaust shall modulate to maintain the total exhaust setpoint minus the total flow of the fume hoods and bio safety

cabinets. The offset shall be adjustable from the BMS Graphical Interface.

3.08 FUME HOODS

- A. Fume hoods shall be variable volume. As each fume hood sash is raised or lowered, a sash sensor shall indicate sash position to the fume hood controller. The controller shall calculate the fume hood open area and control the air volume through the hood to maintain a constant average face velocity of 100 FPM. Each fume hood shall be equipped with a fume hood monitor which provides a digital display of the fume hoods status.
- B. The fume hood controller will provide a visual alarm if the face velocity drops below setpoint for more than 5 seconds (adjustable). The monitor will provide visual and audible alarm if the face velocity drops more than 10% (adjustable) below setpoint for 5 seconds (adjustable). Both the face velocity alarm setpoint and time delay shall be adjustable. An audible alarm silence button shall be provided, but the visual alarm shall remain in "alarm" until the unsafe condition is cleared. Alarms shall automatically reset when the "alarm" condition clears.
- C. The fume hood controller shall provide an "Emergency Purge" button on the display. In the event of an emergency, the operator can initiate an Emergency Purge which will override the 100 FPM face velocity, set the hood to full exhaust, and sound an audible alarm. The hood shall remain in this mode until released by the operator.

3.09 LAB EXHAUST FANS

- A. General Lab Exhaust Fans
 - 1. Start / Stop
 - a. EF-R-1 (VAV) shall operate at all times.
 - b. EF-R-2 and EF-F-3 shall operate in a lead lag sequence.
 - c. Every Tuesday at 8:00 am the single speed fan with the most runtime shall be re-assigned as the standby fan.
 - d. During the weekly changeover, the old standby fan shall start. Once all three fans have been confirmed as operational, the new standby fan shall stop.
 - e. If the lead fan fails to run, the lead-lag order shall switch and an alarm shall be generated.
- B. Operation
 - 1. The BMS shall determine which pressure sensor is reading the lowest duct pressure and shall use that pressure to control the exhaust fans.
 - 2. The fan speed of EF-R-1 shall modulate to maintain the duct pressure sensor at setpoint.
 - 3. Modulate outside air damper to maintain stack velocity. The balancer shall determine the minimum airflow setpoint for each exhaust fans to maintain the minimum air velocity. If the airflow drops below the setpoint, the outside air dampers shall modulate open. If the airflow rises above the setpoint, the outside air damper shall modulate closed.
 - a. To improve control, the operation of the outside air dampers shall be sequenced. One damper shall be designated as primary and the other as secondary. The primary shall modulate from closed to open on a 0-50% call for outside. The secondary shall modulate from closed to open on a 50% to 100% call for outside air.
- C. Alarms:
 - 1. If the fan command does not match the fan proof, an alarm will be displayed and

- recorded on the BMS.
- 2. Anytime the exhaust plenum pressure exceeds the alarm pressure setpoint (-3.5 inches w.c., user adjustable) an alarm will displayed and recorded on the BMS.
- 3. Anytime the exhaust plenum pressure is below the alarm pressure setpoint (-1.0 inches w.c., user adjustable, established by balancer to insure adequate hood velocities) an alarm will displayed and recorded on the BMS.

3.10 LAB SNORKEL VENTS

- 1. The snorkel air valve shall modulate to maintain the net CFM required for each snorkel vent attached to the valve.
- 2. Snorkel air flow shall be accounted for in the lab air balance equation.

3.11 BIO SAFETY CABINETS

- 1. An exhaust air valve shall modulate the airflow to bio safety cabinet.
- 2. A booster fan on each bio safety cabinet shall operate at all times.
- 3. The speed of the each booster fan shall modulate to maintain the duct static pressure downstream of the HEPA filters at 2 inwc.

3.12 FAN POWERED VARIABLE VOLUME TERMINAL UNIT (FPT)

A. System Off:

- 1. Fan off.
- 2. Heating water control valve closed. (if applicable)

B. System Start:

- 1. Automatically by the BMS based on preprogrammed schedule.
- 2. Operator entered command at the BMS.
- 3. Automatically on low space temperature alarm.
- 4. Automatically by tenant override pushbutton.

C. System Operation:

- 1. Fan Control:
 - a. Occupied and Warm Up/Cool Down Mode – The fan shall run continuously.
- 2. Primary Air Damper Control:
 - a. Occupied and Cool down Mode – Damper shall modulate to provide primary airflow between minimum and maximum airflow setpoint to maintain space temperature setpoint.
 - b. Warm-up Mode – Damper shall be closed.
- 3. Hot Water Heating Coil or Radiation Valve (if applicable):
 - a. The valve shall modulate to maintain space temperature at the heating setpoint. The valve shall modulate in sequence with the primary air damper and shall be closed if the primary airflow is greater than the minimum primary heating airflow setpoint.
- 4. Unoccupied Mode: The system shall be off.

D. System Stop:

1. Operator command at the BMS or automatically by the BMS based on a preprogrammed schedule.
2. When the system is called to stop, the system shall revert to that "Off" state as described above.

E. Setpoints:

1. Occupied space temperature 68 degrees F heating and 76 degrees F cooling.
2. Unoccupied space temperature 60 degrees F heating and 82 degrees F cooling
3. Alarm at BMS at +/- 2 degrees F from setpoint.

F. Safeties:

1. Fan shall stop if associated primary air system is shutoff by the fire alarm system.

3.13 FAN COIL UNITS (FCU)

A. System Off:

1. Supply fan off.
2. Chilled water control valve closed. (if applicable)
3. Heating water control valve closed. (if applicable)
4. Control loops inactive.

B. System Start:

1. Automatically by the BMS based on preprogrammed schedule.
2. Operator entered command at the BMS.
3. Local switch.
4. Local temperature sensor.

C. System Operation:

1. The supply fan shall run.
2. The heating coil valve and cooling coil valve shall modulate in sequence to maintain space temperature setpoint.

D. System Stop:

1. Operator command at the BMS or automatically by the BMS based on a preprogrammed schedule.
2. When the system is called to stop, the system shall revert to that "Off" state as described above.

E. Setpoints:

1. Occupied space temperature 68 degrees F heating and 76 degrees F cooling.
2. Unoccupied space temperature 60 degrees F heating and 82 degrees F cooling
3. Alarm at BMS at +/- 2 degrees F from setpoint.

3.14 VARIABLE AIR VOLUME TERMINAL UNIT (VAV)

A. System Start:

1. Automatically by the BMS based on preprogrammed schedule.
2. Operator entered command at the BMS.
3. Automatically by tenant override pushbutton.

- B. System Operation:
 - 1. Primary Air Damper Control:
 - a. Occupied and Cool down Mode: Damper shall modulate to provide primary airflow between minimum and maximum airflow setpoint to maintain space temperature setpoint.
- C. System Stop:
 - 1. Operator command at the BMS or automatically by the BMS based on preprogrammed schedule.
 - 2. When the system is called to stop, the system shall revert to that "Off" state as described above.
- D. Setpoints:
 - 1. Occupied space temperature set point of 76 degrees F. Alarm at BMS at +/- 2 degrees F from setpoint.

3.15 VARIABLE AIR VOLUME AND FAN COIL UNIT PAIRS

- A. In spaces which are served by VAV boxes and FCUs the following sequence shall be supplemental.
 - 1. Both units shall be mapped to a common room temperature sensor. The VAV box shall be the first stage of cooling. This shall be implemented by resetting the cooling setpoint of the FCU to be 2 degrees greater than the VAV box.

3.16 HYDRONIC SYSTEM HEATING / COOLING SWITCH OVER

- All Heating/Cooling switchover temperature and BTU setpoints shall appear on graphics and be user adjustable.
- A. The BMS shall calculate the BTUs of the hot water system and the BTU of the chilled water system by using temperature and flow meter values and the equation: $BTU = 500 * GPM * (\Delta T)$
- B. If the outdoor air temperature is greater than 70 degrees, the system shall switch to Cooling mode.
- C. If the outdoor air temperature is greater than 60 degrees and the Chilled Water BTUs is greater than the Hot Water BTUs, than the mode shall switch to Cooling.
- D. If the outdoor air temperature is less than 55 degrees, and the Chilled Water BTUs is less than the Hot Water BTUs, than the mode shall switch to Heating.
- E. If the outdoor air temperature is less than 45 degrees, the system shall switch to Heating mode.
- F. The system shall only be allowed to switch modes automatically twice per day. Operator shall be able to switch modes with an override at any time.
- G. In cooling mode, the chillers shall be commanded into cooling mode and have the appropriate setpoints updated.
- H. In heating mode, the chillers shall be commanded into heating mode and have the

appropriate setpoints updated.

- I. When switching between modes, the steady state water flow to the chillers shall be maintained throughout the transition. The Controls Contractor shall bear full responsibility for selecting appropriate valve actuators that will allow the necessary timing for smooth transitions from mode to mode. Modulating valves shall be provided in place of 2-position valves in location where a specific open and close rate is required for smooth transitions from mode to mode.
- J. The following chart shows the valve configuration for the heating and cooling modes. Three way valves are shown as "Normal" when flow is through the N.O. port and "Switched" when flow is through the N.C. ports. See drawings for tag references.

| TAG | Function | Heating | Cooling |
|---------|------------------------------------|------------|---------|
| CW-I-V1 | Condenser Water Isolation Valve #1 | Closed | Open |
| CW-I-V2 | Condenser Water Isolation Valve #2 | Switched | Normal |
| CW-I-V3 | Condenser Water Isolation Valve #3 | Switched | Normal |
| HI-R-V | Heat Injection Return Valve | Open | Closed |
| HI-S-V | Heat Injection Supply Valve | Modulating | Normal |

3.17 HEAT EXCHANGER / CONDENSER WATER LOOP

A. System Operation:

1. Cooling Mode:

- a. The heat injection loop isolation valves shall isolate the condenser water from the chilled water.
- b. The condenser water pumps shall start and operate continuously in cooling mode.
- c. The condenser water pump speed shall modulate to maintain the condenser water differential pressure (*CW-DP*) at setpoint.
 - (1) Setpoint to be determined by balancer to achieve design flow through primary condensers
- d. The ground water loop pump speed shall modulate to maintain the condenser water return temperature (*CW-R-T*) at setpoint.
 - (1) Setpoint shall initially be a 64 degrees F

2. Heating Mode:

- a. The condenser water pumps shall stop.
- b. The ground water loop pump speed shall modulate to maintain the condenser water return temperature (*CW-R-T*) at setpoint.
 - (1) Setpoint shall initially be at 56 degrees F

3. Pumps:

- a. When starting the lead pump, the pump speed shall modulate to maintain a temporary setpoint. This setpoint shall linearly ramp from 0PSI to the final setpoint over a 2 minute period.
- b. Pump speed shall modulate to maintain the condenser water loop differential pressure at setpoint. Setpoint shall be determined by balancer.
- c. If the lead pump speed is greater than 95% and the differential pressure is 2 PSI below setpoint for more than 5 minutes, the lag pumps shall ran up and maintain the same speed as the lead pump.
- d. If the sum of the pump speeds is below 85% for more than 5 minutes, the

- lag pumps shall ramp down and stop.
- e. Lead/Lag:
- (1) The BMS shall totalize the runtime of each pump in a lead/lag pump pair.
 - (2) Once per week at 8:00 am, the pump with the most runtime shall be re-assigned as the lag pump.
 - (3) During the weekly changeover, if only one pump is operating, the new lead pump shall start. Once both pumps have been confirmed as operational, the old lead pump shall stop.
 - (4) If the lead pump fails or alarms, then the lead/lag order shall switch and an alarm shall be generated.

B. Alarms:

- a. Alarm at BMS at +/- 5 degrees F from setpoint.
- b. Alarm BMS at +/- 2 PSI from setpoint.
- c. Condenser Water Freeze Alarm: If any condenser water temperature sensor is 38 degrees F or less, an alarm at the BMS indicating low temperature shall notify the operator.

3.18 GROUND WATER LOOP SYSTEM

A. System Operation:

1. Ground water pumps shall operate at all times.
2. Pump speed (see 230993, 3.13, A-1-C and A-2-C)

B. Alarms:

1. Condenser Water Freeze Alarm: If any ground water temperature sensor is 38 degrees F or less, an alarm at the BMS indicating low temperature shall notify the operator.

3.19 CHILLED WATER LOOP

A. System Operation:

1. Cooling Mode:

- a. Operating chiller(s) shall modulate output to maintain the chilled water supply temperature at setpoint.
 - (1) Setpoint shall initially be 44 degrees F
- b. If the lead chiller is operating and the lead chiller's load is greater than 90% for more than 5 minutes and the chilled water supply temperature (*CHW-S-T*) is 4 degrees above setpoint for more than 5 minutes. The lag chiller shall start.
 - (1) When the lag chiller starts, the isolation valves shall open fully before the chiller is enabled.
- c. If both chillers are operating and the sum of both chiller's operating loads is less than 80% for more than 5 minutes, the lag chiller shall stop.
 - (1) When stopping the lag chiller, the chiller shall be disabled. After a 3 minute delay the isolation valves shall close.

- d. The minimum run time and stop time for each chiller is 30 minutes.
2. Heating Mode:
- a. The chilled water supply temperature is maintained by the chillers between an upper and lower limit only.
 - b. The heat injection supply valve (*HI-S-V*) shall modulate to maintain the chilled water return temperature (*CHW-R-T*) at setpoint (initially at 60F). In heating mode, maintain a minimum valve position of 10% to divert a small water flow through the heat exchangers at all time.
3. Chiller Lead/Lag
- a. Chiller Lead/Lag order shall be selected by the operator.
 - (1) If both chiller are operating, no action shall occur until the chiller load dictates that a chiller shall shut down, at which time the new Lag chiller shall stop.
 - (2) If only one chiller is operating and the operator initiates a changeover, the new lead chiller shall be enabled.
 - (a) Once the BMS has confirmed both chillers are operational, the old lead chiller shall be disabled.
4. Chilled Water Bypass Valve
- a. Modulate the chilled water bypass valve (*CHW-BP-V*) to maintain the chilled water flow rate (*CHW-F*) at setpoint. The flow rate setpoint shall reset based on the number of chillers in operation. (see equipment schedule for flow rates) and the position of the heat injection valve.
 - (1) If the heat injection control valve is more than 95% open and the setpoint is less than the maximum flow rate of the total number of operating chillers, the flow rate setpoint shall increase by 100 GPM every 5 minutes.
 - (2) If the heat injection control valve is less than 5% open and the setpoint is greater than the maximum flow rate of the total number of operating chillers, the flow rate setpoint shall decrease by 100 GPM every 5 minutes.
5. Pumps:
- a. When starting the lead pump, the pump speed shall modulate to maintain a temporary setpoint. This setpoint shall linearly ramp from 0PSI to the final setpoint over a 2 minute period.
 - b. Modulate pump speed to maintain the differential pressure (*CHW-DP*) at setpoint.
 - (1) Setpoint shall be determined by balancer.
 - c. If the lead pump speed is greater than 95% and the differential pressure is 2 PSI below setpoint for more than 5 minutes, the lag pumps shall run up and maintain the same speed as the lead pump.
 - d. If the sum of the pump speeds is below 85% for more than 5 minutes, the lag pumps shall ramp down and stop.
 - e. Lead/Lag:
 - (1) The BMS shall totalize the runtime of each pump in a lead/lag pump pair.

- (2) Once per week at 8:00 am, the pump with the most runtime shall be re-assigned as the lag pump.
- (3) During the weekly changeover, if only one pump is operating, the new lead pump shall start. Once both pumps have been confirmed as operational, the old lead pump shall stop.
- (4) If the lead pump fails or alarms then the lead/lag order shall switch and an alarm shall be generated.

B. Alarms:

1. Alarm BMS at +/- 5 degrees F from setpoint.
2. Alarm BMS at +/- 2 PSI from setpoint
3. Alarm BMS at +/- 50 GPM from setpoint.
4. Chilled Water Freeze Alarm: If any chilled water temperature sensor is 38 degrees F or less, an alarm at the BMS indicating low temperature shall notify the operator.

3.20 HEATING HOT WATER LOOP

A. System Operation

1. Cooling Mode:

- a. In cooling mode the hot water system shall be disabled above 70 degrees F and enabled below 65 degrees F.
- b. HW System Enabled

- (1) The heating condenser valves shall route heating water through the chillers' heating condensers.
- (2) The first stage of heating shall be the chillers' heating condensers.
- (3) The hot water supply temperature is maintained by the chillers between an upper and lower limit only.
- (4) If the hot water supply temperature (*HW-S-T*) is less than 10 degrees below setpoint for 5 minutes, then the isolation valve on the lead boiler shall open and the boiler shall be enabled.
- (5) Boiler output shall modulate to maintain the boiler hot water supply at setpoint (*B1-S-T* & *B2-S-T*).
 - (a) Modulate the boiler setpoint between 140 and 170 degrees F to maintain the hot water supply temperature (*HW-S-T*) at setpoint.

- (6) If the lead boiler is operating and supply hot water temperature setpoint is 170 degrees and the supply water temperature (*Bx-S-T*) is below 160 for 10 minutes, then the isolation valve for the lag boiler shall open and the lag boiler shall be enabled.
- (7) Boiler outputs shall modulate to maintain hot water supply (*B1-S-T* and *B2-S-T*) at setpoint.
- (8) If both boilers are operating and the boiler entering water temperature (*B-EW-T*) is within 20 degrees of the boiler setpoint for more than 5 minutes, the lag boiler shall be disabled.
- (9) If only the lead boiler is operating and the boiler entering water temperate (*B-EW-T*) is within 20 degrees of the boiler setpoint for more than 5 minutes, the lead boiler shall be disabled.
- (10) When a boiler is disabled, then a 2 minute delay shall occur before the isolation valve shall close.

- c. HW System Disabled

- (1) Boilers shall be disabled
- (2) HW Pumps shall be disabled

2. Heating Mode:

- a. The hot water condenser valves shall route heating water through the chillers' primary condensers.
- b. The first stage of heating shall be the chillers' primary condensers.
- c. When the chillers are in heating mode, the chillers shall maintain the hot water supply temperature at setpoint.
- d. If one chiller is operating and the chiller's load is greater than 90% for more than 5 minutes and the boiler entering water temperature (*B-EW-T*) is 4 degrees below setpoint for more than 5 minutes. The second chiller shall start.
 - (1) When the lag chiller starts, the isolation valves shall open fully before the chiller is enabled.
- e. If both chillers are operating and the sum of both chiller's operating loads is less than 90% for more than 5 minutes, the lag chiller shall stop.
 - (1) When stopping the lag chiller, the chiller shall be disabled. After a 3 minute delay the isolation valves shall close.
- f. The minimum run time and stop time for each chiller is 30 minutes.
- g. If both chillers are operating and the hot water supply temperature (*HW-S-T*) is 5 degrees below setpoint for 5 minutes, then the isolation valve on the lead boiler shall open and the boiler shall be enabled.
- h. Boiler output shall modulate to maintain the boiler hot water supply at setpoint.
 - (1) Modulate the boiler setpoint between 140 and 170 degrees F to maintain the hot water supply temperature (*HW-S-T*) at setpoint.
- i. If the lead boiler is operating and supply hot water temperature setpoint is 170 degrees and the supply water temperature is below 160 degrees for 10 minutes, then the isolation valve for the lag boiler shall open and the lag boiler shall be enabled.
- j. If the lead boiler is operating and supply hot water temperature is 5 degrees below setpoint for 5 minutes, then the isolation valve for the lag boiler shall open and the boiler shall be enabled.
- k. Boiler output shall modulate to maintain hot water supply at setpoint.
- l. If only the lead boiler is operating and the boiler entering water temperature (*B-EW-T*) is within 20 degrees of the boiler setpoint for more than 5 minutes, the lead boiler shall be disabled.
- m. When a boiler is disabled, a 2 minute delay shall occur before the isolation valve shall close.

3. Pumps:

- a. When starting the lead pump, the pump speed shall modulate to maintain a temporary setpoint. This setpoint shall linearly ramp from 0PSI to the final setpoint over a 2 minute period.
- b. Pump speed shall modulate to maintain the process water loop differential pressure at setpoint. Setpoint shall be determined by balancer.
- c. If the lead pump speed is greater than 95% and the differential pressure is 2 PSI below setpoint for more than 5 minutes, the lag pumps shall run up and maintain the same speed as the lead pump.
- d. If the sum of the pump speeds is below 85% for more than 5 minutes, the

- lag pumps shall ramp down and stop.
- e. Lead/Lag:
- (1) The BMS shall totalize the runtime of each pump in a lead/lag pump pair.
 - (2) Once per week at 8:00 am, the pump with the most runtime shall be re-assigned as the lag pump.
 - (3) During the weekly changeover, if only one pump is operating, the new lead pump shall start. Once both pumps have been confirmed as operational, the old lead pump shall stop.
 - (4) If the lead pump fails or alarms, then the lead/lag order shall switch and an alarm shall be generated.

4. Boiler Lead/lag:

- a. The BMS shall totalize the runtime of boiler.
- b. If both boilers are off, the boiler with the most runtime shall be re-assigned as the lag pump.

B. Alarm:

1. Alarm BMS at +/- 5 degrees F from setpoint.

C. Safeties:

1. Boiler shall be equipped with all safeties as recommended by manufacture and required by codes.

3.21 PROCESS WATER LOOP

A. Temperature Controls

1. The Process Water Temperature control valve (*PW-V*) shall modulate to maintain the supply process water temperature at setpoint (initially 60 degrees F)

B. Pump Controls

1. When starting the lead pump, the pump speed shall modulate to maintain a temporary setpoint. This setpoint shall linearly ramp from 0PSI to the final setpoint over a 2 minute period.
2. Pump speed shall modulate to maintain the process water loop differential pressure at setpoint. Setpoint shall be determined by balancer.
3. If the lead pump speed is greater than 95% and the differential pressure is 2 PSI below setpoint for more than 5 minutes, the lag pumps shall run up and maintain the same speed as the lead pump.
4. If the sum of the pump speeds is below 85% for more than 5 minutes, the lag pumps shall ramp down and stop.
5. Lead/Lag:
 - a. The BMS shall totalize the runtime of each pump in a lead/lag pump pair.
 - b. Once per week at 8:00 am, the pump with the most runtime shall be re-assigned as the lag pump.
 - c. During the weekly changeover, if only one pump is operating, the new lead pump shall start. Once both pumps have been confirmed as operational, the old lead pump shall stop.
 - d. If the lead pump fails or alarms, then the lead/lag order shall switch and an alarm shall be generated.

C. Alarm:

1. Alarm BMS at +/- 5 degrees F from setpoint.

3.22 ELECTRIC SWITCHGEAR AIR CONDITIONING SYSTEMS

A. System Off:

1. Fan shall be off.
2. Chilled water valve closed.

B. System Start:

1. Locally from space thermostat.

C. System Operation:

1. The re-circulating supply fan shall be controlled by a space thermostat to maintain an adjustable set space temperature. On a rise in temperature above 85 degrees F adjustable, the thermostat shall energize the supply fan. On a drop in space temperature below 80 degrees F, the space thermostat shall de-energize the supply fan. The chilled water valve shall modulate open when the supply fan starts.

D. System Stop:

1. On a drop in space temperature below 80 degrees F revert to the system off state.

E. Setpoints:

1. System on at 85 degrees F; system off at 80 degrees F.

F. Safeties:

1. Provide high room temperature alarm at the BMS.

3.23 LABORATORY CHILLED WATER SYSTEM

A. The chilled water system shall operate at all times.

B. The BMS shall communicate to the chiller by the BACnet protocol.

1. The BMS shall command the chiller to start / stop.
2. The BMS shall reset the supply water setpoint.

C. Pumps:

1. When starting the lead pump, the pump speed shall modulate to maintain a temporary setpoint. This setpoint shall linearly ramp from 0PSI to the final setpoint over a 2 minute period.
2. Pump speed shall modulate to maintain the chilled water loop differential pressure at setpoint. Setpoint shall be determined by balancer.
3. If the lead pump speed is greater than 95% and the differential pressure is 2 PSI below setpoint for more than 5 minutes, the lag pumps shall run up and maintain the same speed as the lead pump.
4. If the sum of the pump speeds is below 85% for more than 5 minutes, the lag pumps shall ramp down and stop.
5. Lead/Lag:
 - a. The BMS shall totalize the runtime of each pump in a lead/lag pump pair.
 - b. Once per week at 8:00 am, the pump with the most runtime shall be re-

- assigned as the lag pump.
- c. During the weekly changeover, the new lead pump shall ramp up to the same speed as the old lead pump over a 2 minute period. Once both pumps have been confirmed as operational, the old lead pump shall ramp down and stop over a 2 minute period.
- d. If the lead pump fails or alarms, then the lead/lag order shall switch and an alarm shall be generated.
- e. If the lead pump fails or alarms, then the lead/lag order shall switch and an alarm shall be generated.

D. Alarm:

- 1. Alarm BMS at +/- 5 degrees F from setpoint.
- 2. Alarm BMS at +/- 2 PSI from setpoint.
- 3. Monitor chiller and VFDs for alarms.

E. Safeties:

- 1. Chilled Water Freeze Alarm: If any temperature sensor is 34 degrees F or less, an alarm at the BMS indicating low temperature shall notify the operator.

3.24 REFRIGERATION MACHINERY ROOM VENTILATION

A. System Off:

- 1. Exhaust fan shall be off.
- 2. Outside air damper shall be closed

B. System Start:

- 1. Operator entered command at the BMS.
- 2. Automatically by the BMS based on space temperature sensor.
- 3. Automatically based on activation of the chiller plant emergency fan operation switch.
- 4. Automatically by the BMS based on input from the refrigerant monitoring system.

C. System Operation:

- 1. If fan is starting based on temperature, the outside air damper shall open 30 seconds before the fan starts.
- 2. If the fan is starting based on emergency fan switch or refrigerant leak detection, the fan shall start and the dampers shall open simultaneously.
- 3. Fans shall cycle on and off to satisfy space temperature setpoints.
- 4. Fans on due to emergency fan switch or refrigerant leak detection.

D. System Stop:

- 1. Operator entered command at the BMS.
- 2. Space temperature is below setpoint.
- 3. Shutdown switch or leak detection alarm is reset.

E. Setpoints:

- 1. Space temperature setpoint 75 degrees F +/-10 degrees.

F. Alarms:

- 1. Fan failure based on proof of airflow.

3.25 TOILET EXHAUST AND ELECTRIC CLOSET EXHAUST FANS

- A. System Off:
 - 1. Fans off.
- B. System Start:
 - 1. Automatically by the BMS based on preprogrammed schedule.
 - 2. Operator entered command at the BMS.
- C. System Operation:
 - 1. Fans start.
- D. System Stop:
 - 1. Operator command at the BMS or automatically by the BMS based on a preprogrammed schedule.
 - 2. When the system is called to stop, the system shall revert to that "Off" state as described above.
- E. Alarms:
 - 1. Fan failure.

3.26 INPUT/OUTPUT SUMMARY SHEETS

- A. The following pages provide a list of input/output points. The Contractor shall provide necessary hardware and software including sensors and wiring.
- B. Contractor shall coordinate this points list with the control drawings M6.01, M6.02, and M6.03 and the BMS Sequence of Operations.

Heat Recovery Ventilator (Typ x2)

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|---------|----------------|---------------|--------------------|----------------|--------|-------------|-----------------|------------|-------------|------------|-----------------|-----------------|-------|---------------|----------|-----------------|----------------|--|--|--|--|--|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | DIGITAL | | | | | SYSTEM FEATURES | | | | | | | | | KEY TO NOTES | | | | | | |
| | INPUT | | | OUTPUT | | INPUT | | | OUTPUT | | ALARMS | | | | PROGRAMS | | | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | AIRFLOW | SET POINT ADJ. | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | | MORNING WARMUP | | | | | |
| Return Air | X | | X | | | | | | | | | | | | | | | | | | | | | | | |
| Return Filter DP | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| Evap Spray Pump | | | | | | | | | X | | | | | | | | | | | | | | | | | |
| Evap Spray Drain | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| Evap Spray Mayup | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| Exhaust Air Temp | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| Outside Air Temp | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| Outside Air Flow | | | | X | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | |

Heat Recovery Ventilator (Typ x2)

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|----------------|----------|---------------|--------------------|----------------|--------|-------------|-------------|------------|-----------------|------------|-----------------|-----------------|-------|---------------|----------|----------------|----|--|--|-----------------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | | | | KEY TO NOTES |
| | INPUT | | | OUTPUT | | | INPUT | | | OUTPUT | | | ALARMS | | | | | PROGRAMS | | | | | | |
| | TEMPERATURE | PRESSURE | RH | SET POINT ADJ. | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP | | | | |
| Outside Air Damper | | | | | | X | | | X | | | | | | | | X | | | | 1. | | | |
| Outside Air Filter | X | | | | | | | | | | | | | | | | X | | | | | | | |
| Pre Coil Air Temp | X | | | | | | | | | | | | | | | | X | | | | | | | |
| Heating Coil Valve | | | | X | | | | | | | | | | | | | X | | | | | | | |
| Cooling Coil Valve | | | | X | | | | | | | | | | | | | X | | | | | | | |
| Low Temp Det | | | | | X | | | | | | | | X | | | | X | | | | 1 | | | |
| HW Coil Disc Temp | X | | | | | | | | | | | | | | | | X | | | | | | | |
| Hi Static Safety | | X | | | | | | | X | | | | | | | | X | | | | 1. | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Hardwire safety to VFD. | | | | | | | | | | | | | | | | | | | | | | | | |

Heat Recovery Ventilator (Typ x2)

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|----------------|-------|----------|---------------|--------------------|----------------|--------|-------------|-------------|-----------------|-------------|------------|-----------------|-----------------|-------|---------------|----------|-----------------|----------------|--|-------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | |
| | INPUT | | | OUTPUT | | | INPUT | | | OUTPUT | | | ALARMS | | | | PROGRAMS | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | SET POINT ADJ. | SPEED | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | | MORNING WARMUP | | |
| Supply Air | X | | X | | | | | | | | X | X | | | | | | X | | | | | | |
| Supply Static Press | | X | | | | | | | | | | | | | | | | X | | | | | | |
| Supply Fan | | | | | X | X | | | X | | | | | | | | | X | X | | | | | 1,2,3 |
| Supply Damper | | | | | | | X | | | X | | | | | | | | X | X | | | | | 4 |
| Building Static Pressure 1st floor | | X | | | | | | | | | X | X | | | | | | X | | | | | | 5,6 |
| Building Static Pressure 2nd floor | | X | | | | | | | | | X | X | | | | | | X | | | | | | 5,6 |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |
| <ol style="list-style-type: none"> 1. Integrate to VFD with BMS network to provide access to all available VFD points. 2. One VFD drives 9 supply fans as part of the supply fan wall system 3. The status of each of the 9 supply fans shall be monitored. Current sensing relays shall be configured such that if any fan fails an alarm is generated. 4. <u>Hardwire end switch to VFD.</u> 5. Locate indoor pressure reference in corridor. 6. One first floor sensor shall server HRV-1 and HRV-2 simultaneously. 7. One second floor sensor shall server HRV-1 and HRV-2 simultaneously. | | | | | | | | | | | | | | | | | | | | | | | | |

Heat Recovery Ventilator (Typ x2)

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|----------------|-------|----------|---------------|--------------------|----------------|--------|--|--------|-----------------|--|-------------|------------|-------------|------------|--|--|-----------------|-----------------|-----------------|-------|---------------|----------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | | | |
| | INPUT | | | OUTPUT | | | INPUT | | | OUTPUT | | | ALARMS | | | | PROGRAMS | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | SET POINT ADJ. | SPEED | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | OFF-ON | OPEN-CLOSED | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME |
| Heat pipe bypass | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Heat pipe face | | | | | | X | | | | | | | | | | | | | | | | | X | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. | | | | | | | | | | | | | | | | | | | | | | | | | | |

Office AHUs (Typ x3)

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-----|--------|----------------|-------|----------|---------------|--------------------|----------------|--------|---|--------|-----------------|---|-------------|------------|-------------|------------|--|--|-----------------|-----------------|-------|-----------------|---------------|----------|----------------|--|---|--|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | | DIGITAL | | | | | | | SYSTEM FEATURES | | | | | | | | | | | KEY TO NOTES | | | | | | |
| | INPUT | | | | OUTPUT | | | INPUT | | | | OUTPUT | | | ALARMS | | | | | PROGRAMS | | | | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | CO2 | FLOW | SET POINT ADJ. | SPEED | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | OFF-ON | OPEN-CLOSED | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | TIME SCHEDULING | OPT. START/STOP | RESET | | COLOR GRAPHIC | RUN TIME | MORNING WARMUP | | | |
| Return Air | X | | X | X | | | | | | | | | | | | X | X | | | | | | | | | X | | | | | | |
| Return Air Fan | | | | | | X | | X | | | | | X | | | | | | | | | | | | | X | X | | | | 1 | |
| Supply Air Fan | | | | | | X | | X | | | | | X | | | | | | | | | | | | | X | X | | | | 1 | |
| Mixed Air Dampers | | | | | | | X | | | | | | | | | | | | | | | | | | | X | | | | | | |
| Outdoor Air | X | | | X | | | | | | | | | | | | X | X | | | | | | | | | X | | | | | | |
| Minimum OSA Dmpr | | | | | | | X | | | | | | | | | | | | | | | | | | | X | | | | | | |
| Indirect Evaporative Cooling | | | | | | | | | | | | | X | | | | | | | | | | | | | X | X | | | | | |
| Indirect Evaporative Cooling Sup Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | | X | | | | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Integrate to VFD with BMS network to provide access to all available VFD points. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Office AHUs (Typ x3)

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|----------------|----------|---------------|--------------------|----------------|--------|-------------|-------------|------------|-----------------|------------|-----------------|-----------------|----------|---------------|----------|----------------|-----------------|--|--|---|--|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | | |
| | INPUT | | | OUTPUT | | | INPUT | | | OUTPUT | | | ALARMS | | | | PROGRAMS | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | SET POINT ADJ. | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP | | | | | |
| Mixed Air Temp | X | | | | | | | | | | X | X | | | | | X | | | | | | | | |
| Filter DP | | X | | | | | | | | | | | | | | | | X | | | | | | | |
| Heating Coil Valve | | | | X | | | | | | X | X | | | | | | | X | | | | | | | |
| Low Temp Det | | | | | | X | | | | | | | | | | | | X | | | | | | 1 | |
| HW Coil Disc Temp | X | | | | | | | | | | X | X | | | | | | X | | | | | | | |
| Chilled Coil Valve | | | | X | | | | | | | | | | | | | | X | | | | | | | |
| Supply Air | X | X | X | | | | | | | | X | X | | | | | | X | | | | | | | |
| Hi Static Safety | | X | | | | | | | | | | | | | | | | X | | | | | | 1 | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Hardwire safety to VFD. | | | | | | | | | | | | | | | | | | | | | | | | | |

Office AHUs (Typ x3)

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|-------------|----------|----|----------------|----------|---------------|--------------------|----------------|--------|-------------|-------------|------------|-----------------|------------|-----------------|-----------------|-------|---------------|----------|----------------|--|--|-----------------|--|--|-----|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | | | KEY TO NOTES | | | |
| | INPUT | | | OUTPUT | | | INPUT | | | OUTPUT | | | ALARMS | | | | | PROGRAMS | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | SET POINT ADJ. | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP | | | | | | |
| Supply Damper | | | | | | X | | | | | | | | | | | | | | | | | | | | 1,2 |
| Building Static Pressure Sensor | X | | | | | | | | | | | | | X | X | | | | | | | | | | | 3,4 |
| Outside Air Damper | | | | | X | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <ol style="list-style-type: none"> 1. Hardwire <u>safety end switch</u> to VFD. 2. Supply Dampers on RTU-4 and RTU-5 only 3. One sensor shall serve RTU-3 and one sensor shall serve RTU-3 and RTU-4 simultaneously. 4. Locate indoor reference in corridors near main entrance. | | | | | | | | | | | | | | | | | | | | | | | | | | |

Mechanical Room Ventilation

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|--|-------------|----------|----|-----|----------------|----------|---------------|--------------------|----------------|-------------|---------------|--------|-----------------|-------------|------------|-------------|------------|-----------------|-----------------|-------|-----------------|---------------|----------|----------------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | | OUTPUT | | ALARMS | | | | PROGRAMS | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | PPM | SET POINT ADJ. | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | ALARM LEVEL | WARNING LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | | COLOR GRAPHIC | RUN TIME | MORNING WARMUP |
| EF-1-1 | | | | | | X | | | | | X | | | | | | | | | | X | X | | |
| Outside Air Damper | | | | | X | | | | | | | | | | | | | | | | X | | | |
| Space Temperature | X | | | | | | | | | | | | | | | | | | | | X | | | |
| Refrigerant Level | | | X | | | | | | X | X | | | X | | X | | | | | | X | X | | |
| Refrigerant Emergency Ventilation Switch | | | | | | X | | | | | | | | | X | | | | | | X | | | 1 |
| EF-R-4 | | | | | | X | | | | | X | | | | | | | X | | | X | X | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Break-glass type switch. Hardwire to EF-1-1 and damper. | | | | | | | | | | | | | | | | | | | | | | | | |

Misc Points

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|-------------|------------|-------------|----------------|---------------|--------------------|----------------|--------|-------------|-----------------|------------|-------------|------------|-----------------|-----------------|-------|---------------|----------|-----------------|----------------|--|----|--|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | DIGITAL | | | | | SYSTEM FEATURES | | | | | | | | | KEY TO NOTES | | | | |
| | INPUT | | | | OUTPUT | INPUT | | | OUTPUT | | ALARMS | | | | PROGRAMS | | | | | | | | | |
| | TEMPERATURE | ENERGY RATE | ENERGY USE | TOTAL USAGE | SET POINT ADJ. | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | | MORNING WARMUP | | | |
| Domestic Water Flow Meter | | | X | | | | | | | | | | | | | | X | | | | | | 1. | |
| Air Comp Alarm | | | | | | X | | | | X | | | | | | | X | | | | | | | |
| Vacuum Sys Alarm | | | | | | X | | | | | | | | | | | X | | | | | | | |
| Generator Run Stat | | | | | | X | | | | | | | | | | | X | X | | | | | | |
| Pure Water System Alarm | | | | | | X | | | | | | | | | | | X | | | | | | | |
| Natural Gas Meter | | | X | | | | | | | | | | | | | | X | | | | | | 1. | |
| Square D Electrical Meters | X | X | | | | | | | | | | | | | | | X | | | | | | 2 | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Provide sufficient point quantity and type to provide a totalize water usage value. 2. Ingrate BMS with Square D Electrical Meter and provide access to all available data. | | | | | | | | | | | | | | | | | | | | | | | | |

Misc Points

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|-------------|------------|-------------|----------------|--|---------|---------------|--------------------|----------------|--|---|-----------------|-------------|---|-------------|------------|-------------|------------|--|-----------------|--|-----------------|-----------------|-------|---------------|----------|----------------|----|----|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | | | | | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | OUTPUT | | | ALARMS | | | | PROGRAMS | | | | | | | | | | | | | |
| | TEMPERATURE | ENERGY RATE | ENERGY USE | TOTAL USAGE | SET POINT ADJ. | | | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | OFF-ON | OPEN-CLOSED | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP | | |
| Cold Room Monitor | X | | | | | | | | | | | | | | X | X | | | | | | | | | X | | | | | 1. |
| Toilet Exhaust Fan | | | | | | | X | | | | | X | | | | | | | | | | | | | X | X | | | 1. | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES 1. Typical – See drawings for quantities. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Process Steam / Outdoor Points

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-------------|-----|----------------|---------------|--------------------|----------------|--------|--|--------|-----------------|---|-------------|------------|-------------|------------|----------|--|--|--|--|--|-----------------|---|---|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | | | | | KEY TO NOTES | | |
| | INPUT | | | | | OUTPUT | INPUT | | | OUTPUT | | | ALARMS | | | | | | PROGRAMS | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | CO2 | SET POINT ADJ. | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | OFF-ON | OPEN-CLOSED | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | | | | | | | |
| Steam Generator | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| Steam Generator Alarm | | | | | | | X | | | | | | | | | | X | | | | | | | | | X | X |
| Steam Pressure | | X | | | | | | | | | | | | X | X | | | | | | | | | | | X | |
| Outdoor Air | X | | X | | X | | | | | | | | | X | X | | | | | | | | | | X | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Ground Water System

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-----------------|----------------|-------|---------------|--------------------|----------------|--------|-------------|-------------|-----------------|-------------|------------|-----------------|-----------------|-------|---------------|----------|-----------------|----------------|-------|--|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | OUTPUT | | | ALARMS | | | | PROGRAMS | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | FLOW RATE (GPM) | SET POINT ADJ. | SPEED | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | | MORNING WARMUP | | |
| Ground Water Supply | X | | | X | | | | | | | X | X | | | | | | X | | | | | | |
| Common Ground Return | X | | | X | | | | | | | X | X | | | | | | X | | | | | | |
| HX-1 Return Temp | X | | | | | | | | | | X | X | | | | | | X | | | | | | |
| HX-2 Return Temp | X | | | | | | | | | | X | X | | | | | | X | | | | | | |
| Ground Water Pump | | | | | X | X | | | X | | | | | | | | | X | X | | | | 1,2,3 | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Integrate to VFD with BMS network to provide access to all available VFD points. | | | | | | | | | | | | | | | | | | | | | | | | |
| 2. See Civil Drawing for number of pumps and pump designations. | | | | | | | | | | | | | | | | | | | | | | | | |
| 3. Typical x2 | | | | | | | | | | | | | | | | | | | | | | | | |

Lab Exhaust

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|---------------|----------------|----------|---------|---------------|--------------------|----------------|--|---|-----------------|-------------|---|-------------|------------|-------------|------------|--|--|-----------------|-----------------|-----------------|-------|---------------|----------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | | | KEY TO NOTES | | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | OUTPUT | | | ALARMS | | | | | PROGRAMS | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | AIRFLOW (CFM) | SET POINT ADJ. | POSITION | SPEED | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | OFF-ON | OPEN-CLOSED | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | TIME SCHEDULING | | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME |
| Duct Static Press | X | | | | | | | | | | | | | | X | X | | | | | | | | X | | | 4 |
| Duct Static Press | X | | | | | | | | | | | | | | X | X | | | | | | | | X | | | 5 |
| EF-R-x Airflow | | | X | | | | | | | | | | | | X | X | | | | | | | | X | | | 3 |
| EF-R-1 Fan (VFD) | | | | | | X | X | | | | | X | | | | | X | X | | | | | | X | X | | 1 |
| EF-R-2/3 (Starters) | | | | | | | X | | | | | X | | | | | X | X | | | | | | X | X | | 2 |
| Outside Air Damper | | | | | X | | | | | | | | | | | | | | | | | | | X | | | 2 |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Integrate to VFD with BMS network to provide access to all available VFD points. | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2. Typ x2 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3. Typ x3 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4. HRV-1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5. HRV-2 | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System - Temperature

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-------------|----------------|---------------|--------------------|----------------|--------|-------------|-------------|------------|-----------------|------------|-----------------|-----------------|----------|---------------|----------|----------------|-----------------|--|--|-----------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | | OUTPUT | | ALARMS | | | | PROGRAMS | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | SET POINT ADJ. | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP | | | | |
| CHW Sup Temp | X | | | | | | | | | | X | X | | | | | X | | | | | | | CHW-S-T |
| CHW Ret Temp #1 | X | | | | | | | | | | X | X | | | | | X | | | | | | | CHW-R-T1 |
| CHW Ret Temp #2 | X | | | | | | | | | | X | X | | | | | X | | | | | | | CHW-R-T2 |
| Evap 1 Sup Temp | X | | | | | | | | | | X | X | | | | | X | | | | | | | EVAP1-S-T |
| Evap 2 Sup Temp | X | | | | | | | | | | X | X | | | | | X | | | | | | | EVAP2-S-T |
| Evap Ent Water Temp | X | | | | | | | | | | X | X | | | | | X | | | | | | | EVAP-EW-T |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System - Temperature

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-------------|----------------|---------------|--------------------|----------------|--------|-------------|-----------------|------------|-------------|------------|-----------------|-----------------|-------|---------------|-----------------|----------|----------------|--|--|--|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | DIGITAL | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | | | |
| | INPUT | | | OUTPUT | | INPUT | | | OUTPUT | | ALARMS | | | | PROGRAMS | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | SET POINT ADJ. | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | | RUN TIME | MORNING WARMUP | | | |
| Primary Cond 1 Sup Temp | X | | | | | | | | | | X | X | | | | | X | | | | PC1-S-T | | | |
| Primary Cond 2 Sup Temp | X | | | | | | | | | | X | X | | | | | X | | | | PC2-S-T | | | |
| Hot Condenser 1 Sup Temp | X | | | | | | | | | | X | X | | | | | X | | | | HC1-S-T | | | |
| Hot Condenser 2 Sup Temp | X | | | | | | | | | | X | X | | | | | X | | | | HC2-S-T | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System - Temperature

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-------------|----------------|---------------|--------------------|----------------|--------|-------------|-----------------|------------|-------------|------------|-----------------|-----------------|-------|---------------|----------|-----------------|----------------|--|--|---------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | DIGITAL | | | | | SYSTEM FEATURES | | | | | | | | | KEY TO NOTES | | | | |
| | INPUT | | | | OUTPUT | INPUT | | | OUTPUT | | ALARMS | | | | PROGRAMS | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | SET POINT ADJ. | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | | MORNING WARMUP | | | |
| Cond Water Sup Temp | X | | | | | | | | | | X | X | | | | | X | | | | | | | CW-S-T |
| Cond Water Ret Temp #1 | X | | | | | | | | | | X | X | | | | | X | | | | | | | CW-R-T1 |
| Cond Water Ret Temp #2 | X | | | | | | | | | | X | X | | | | | X | | | | | | | CW-R-T2 |
| HX-1 Supply | X | | | | | | | | | | X | X | | | | | X | | | | | | | HX1-S-T |
| HX-2 Supply | X | | | | | | | | | | X | X | | | | | X | | | | | | | HX2-S-T |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System - Temperature

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-------------|----------------|--|---------|---------------|--------------------|----------------|--------|--|-----------------|-------------|--|---|-------------|------------|-------------|------------|-----------------|--|--|--|--|-----------------|-----------------|-------|---------------|----------|----------------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | | | | | | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | | OUTPUT | | ALARMS | | | | PROGRAMS | | | | | | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | SET POINT ADJ. | | | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | OFF-ON | OPEN-CLOSED | | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | | | | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP |
| HW Sup Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | HW-S-T |
| HW Ret Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | HW-R-T |
| Boiler 1 Sup Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | B1-S-T |
| Boiler 2 Sup Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | B2-S-T |
| Boiler Entering Water Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | B-EW-T |
| Process Water Return Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | PW-R-T |
| Process Water Supply Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | PW-S-T |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System – Valves

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-------------|----------------|----------|---------------|--------------------|----------------|--------|--|--|-----------------|-------------|--|-------------|------------|-------------|------------|--|--|-----------------|-----------------|-----------------|-------|---------------|----------|----------------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | | | KEY TO NOTES | | | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | OUTPUT | | | ALARMS | | | | | PROGRAMS | | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | SET POINT ADJ. | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | | OFF-ON | OPEN-CLOSED | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | TIME SCHEDULING | | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP |
| Heat Injection Supply Valve | | | | | X | | | | | | | | | | | | | | | | | | | X | | | | HI-S-V |
| Heat Injection Return Valve | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | HI-R-V |
| Process Water Valve | | | | | X | | | | | | | | | | | | | | | | | | | X | | | | PW-V |
| Condenser Water Iso Valve #1 | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | CW-I-V1 |
| Condenser Water Iso Valve #2 | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | CW-I-V2 |
| Condenser Water Iso Valve #3 | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | CW-I-V3 |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System – Valves

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-------------|----------------|----------|---------------|--------------------|----------------|--------|-------------|-------------|-----------------|-------------|------------|-----------------|-----------------|-------|-----------------|---------------|----------|----------------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | KEY TO NOTES | | | |
| | INPUT | | | OUTPUT | | | INPUT | | | OUTPUT | | | ALARMS | | | PROGRAMS | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | SET POINT ADJ. | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | | COLOR GRAPHIC | RUN TIME | MORNING WARMUP |
| Hot Condenser #1 Iso Valve | | | | | | | | | | X | | | | | | | | | X | | | HC1-V |
| Hot Condenser #2 Iso Valve | | | | | | | | | | X | | | | | | | | | X | | | HC2-V |
| Primary Condenser #1 Iso Valve | | | | | | | | | | X | | | | | | | | | X | | | PC1-V |
| Primary Condenser #2 Iso Valve | | | | | | | | | | X | | | | | | | | | X | | | PC2-V |
| | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System – Valves

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-----------------|----------------|----------|---------------|--------------------|----------------|--------|--|--------|-----------------|--|--|-------------|------------|-------------|------------|--|--|-----------------|-----------------|-----------------|-------|---------------|----------|----------------|----------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | | | KEY TO NOTES | | | | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | OUTPUT | | | ALARMS | | | | | PROGRAMS | | | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | FLOW RATE (GPM) | SET POINT ADJ. | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | OFF-ON | OPEN-CLOSED | | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | TIME SCHEDULING | | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP | |
| Boiler #1 Isolation Valve | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | B1-V |
| Boiler #2 Isolation Valve | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | B2-V |
| Evaporator #1 Isolation Valve | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | EVAP1-V |
| Evaporator #2 Isolation Valve | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | EVAP2-V |
| Boiler Bypass Valve | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | B-BP-V |
| Chilled Water Bypass Valve | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | CHW-BP-V |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System – Flow Meters and Pressure Sensors

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-----------------|----------------|----------|---------------|--------------------|----------------|--------|-------------|-------------|-----------------|-------------|------------|-----------------|-----------------|-------|---------------|----------|-----------------|----------------|--|-------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | OUTPUT | | | ALARMS | | | | PROGRAMS | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | FLOW RATE (GPM) | SET POINT ADJ. | POSITION | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | OFF-ON | OPEN-CLOSED | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | | MORNING WARMUP | | |
| HW Flow | | | X | | | | | | | | | | | X | X | | | | X | | | | | HW-F |
| Cond. Water Flow | | | X | | | | | | | | | | | X | X | | | | X | | | | | CW-F |
| Chilled Water Flow | | | X | | | | | | | | | | | X | X | | | | X | | | | | CHW-F |
| Process Water Press | | X | | | | | | | | | | | | X | X | | | | X | | | | | PW-DP |
| HW Diff Press | | X | | | | | | | | | | | | X | X | | | | X | | | | | HW-DP |
| Cond. Diff Press | | X | | | | | | | | | | | | X | X | | | | X | | | | | CW-DP |
| Chilled Water Press | | X | | | | | | | | | | | | X | X | | | | X | | | | | CH-DP |
| Boiler Diff Press | | X | | | | | | | X | | | | | X | X | | | | X | | | | | B-DP |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System - Pumps

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|-------------|----------|----|-------------|----------------|-------|---------------|--------------------|----------------|--------|---|--------|-----------------|--|--|-------------|------------|-------------|-----------------|------------|--|--|-----------------|-----------------|-------|---------------|----------|----------------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | KEY TO NOTES | | | | | | | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | OUTPUT | | | ALARMS | | | | PROGRAMS | | | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | SET POINT ADJ. | SPEED | STATUS ON/OFF | STATUS OPEN/CLOSED | HIGH-LOW LEVEL | | | OFF-ON | OPEN-CLOSED | | | HIGH ANALOG | LOW ANALOG | HIGH BINARY | | LOW BINARY | | | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP |
| Chilled Water Pumps | | | | | X | X | | | | | X | | | | | | | | | | | | | X | X | | | 1,2 |
| Condenser Water Pumps | | | | | X | X | | | | | X | | | | | | | | | | | | | X | X | | | 1,2 |
| Hot Water Pumps | | | | | X | X | | | | | X | | | | | | | | | | | | | X | X | | | 1,2 |
| Process Condenser Water Pumps | | | | | X | X | | | | | X | | | | | | | | | | | | | X | X | | | 1,2 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Integrate to VFD with BMS network to provide access to all available VFD points. | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2. Typ x2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System – Chillers and Boilers

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|-------------|----------|----|-------------|-------------------|------------------|--------------------|----------|---------------|--------------------|-------|--|--------|--------|-------------|-------------------|-----------------|------------|-------------|------------|----------|--|-----------------|-----------------|-----------------|-------|---------------|----------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | | | DIGITAL | | | | | | | | SYSTEM FEATURES | | | | | | | | KEY TO NOTES | | | |
| | INPUT | | | | OUTPUT | | | | INPUT | | | | OUTPUT | | | | ALARMS | | | | PROGRAMS | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | HOT COND SETPOINT | EVAPORATOR SETPT | PRIMARY COND. STPT | SETPOINT | STATUS ON/OFF | STATUS OPEN/CLOSED | ALARM | | | OFF-ON | OPEN-CLOSED | HEATING / COOLING | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | TIME SCHEDULING | OPT. START/STOP | | RESET | COLOR GRAPHIC | RUN TIME |
| Chillers | | | | | X | X | X | | | X | | | X | | X | X | X | | | | | | | | X | X | | 1,2 |
| Boilers | | | | | | | X | | | X | | | X | | | | | | | | | | | | X | X | | 2 |
| Boiler Emergency Stop Button | | | | | | | | X | | | | | | | | | | | X | | | | | | X | | | 3 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GENERAL NOTES 1. Integrate Chiller with BMS network to provide access to all available Chiller points. 2. Typical x2 3. Hardwire to Boiler | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Hydronic System – Lab Chilled Water System

| SYSTEM POINT LIST | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|-------------|----------|----|-------------|----------|-------|---------|--|---------------|--------------------|-------|--|-----------------|--------|-------------|-------------------|-------------|------------|-------------|------------|--|--|-----------------|-----------------|-----------------|-------|---------------|----------|----------------|-------|
| EQUIPMENT TAG AND POINT DESCRIPTION | ANALOG | | | | | | DIGITAL | | | | | | SYSTEM FEATURES | | | | | | | | | | KEY TO NOTES | | | | | | | |
| | INPUT | | | | OUTPUT | | INPUT | | | OUTPUT | | | ALARMS | | | | | PROGRAMS | | | | | | | | | | | | |
| | TEMPERATURE | PRESSURE | RH | TOTAL USAGE | SETPOINT | SPEED | | | STATUS ON/OFF | STATUS OPEN/CLOSED | ALARM | | | OFF-ON | OPEN-CLOSED | HEATING / COOLING | HIGH ANALOG | LOW ANALOG | HIGH BINARY | LOW BINARY | | | | TIME SCHEDULING | OPT. START/STOP | RESET | COLOR GRAPHIC | RUN TIME | MORNING WARMUP | |
| Chiller #3 | | | | | X | | | | | X | | | X | | X | X | X | | | | | | | | X | X | | | | 1,4 |
| Supply Glycol Temperature | X | | | | | | | | | | | | | | | X | X | | | | | | | | X | | | | | 4 |
| Return Glycol Temperature | X | | | | | | | | | | | | | | | X | X | | | | | | | | X | | | | | 4 |
| Chilled Water Supply Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | X | | | | | 4 |
| Chilled Water Return Temp | X | | | | | | | | | | | | | | | X | X | | | | | | | | X | | | | | 4 |
| Chilled Water Diff Pressure | | X | | | | | | | | | | | | | | X | X | | | | | | | | X | | | | | 4 |
| CHWP-3&4 | | | | | | X | | | X | X | | | X | | | | | | | | | | | | X | X | | | | 2,3,4 |
| GENERAL NOTES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <ol style="list-style-type: none"> 1. Integrate Chiller with BMS network to provide access to all available Chiller points. 2. Integrate to VFD with BMS network to provide access to all available VFD points. 3. Typical x2 4. All controls on the Lab Chilled Water System shall be powered from emergency power circuit. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

SECTION 23 21 01

HYDRONIC SYSTEMS SPECIALTIES

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this section shall include, but is not limited to the following:

1. Air vents
2. Air separators
3. Relief valves
4. Suction diffuser
5. Expansion tanks
6. ~~Glycol~~

1.02 SUBMITTALS

- A. Product Data: Certified manufacturer's latest published data indicating performance data, catalog cuts, model numbers, materials of construction, dimensional information, and pressure rating and pressure drops.
- B. ASME Pressure Vessel Forms.
- C. Submit manufacturer analysis of installed glycol solution.

1.03 QUALITY ASSURANCE

- A. Comply with the applicable requirements of ASME, ANSI, UL, ASTM and National Electric Code.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Air Vents: Armstrong, Bell & Gossett, Sarco, Hoffman, Amtrol
- B. Air Separators: ~~Spirotherm, Taco, Caleffi, Armstrong, Bell & Gossett, Amtrol~~
- C. Relief Valves: Armstrong, Bell & Gossett, Amtrol, McDonnell Miller, Kunkle
- D. Suction Diffusers: Armstrong, Bell & Gossett
- E. Expansion Tanks: Armstrong, Bell & Gossett, Amtrol, Taco, Wessels
- F. Ethylene Glycol: Dow Chemical Dowtherm SR-1 or Union Carbide Ucartherm

2.02 AIR VENTS

- A. Provide air vents with 3/4-inch IPS inlet connection and 3/8-inch outlet, suitable for the system and for the system working pressure and temperature. Design vents to eliminate air from the system automatically without permitting the passage of water. Construct vents of brass or semi-steel body, copper float and stainless steel valve parts.

2.03 AIR SEPARATORS

- A. In-Line Air Separator: Provide as indicated on Drawings, a horizontal in-line air separator designed to effectively separate free air in water systems. Construct the air separator of heavy-duty cast iron designed to function satisfactorily at working pressures up to 175 pounds per square inch and liquid temperatures to 300 degrees F. Provide an integral weir designed to decelerate system flow to maximize air separation.
- B. Coelescing Centrifugal Air Separator:
1. Provide as indicated on Drawings, a coelescing centrifugal type air separator. Select unit at point of peak efficiency for system flow. Provide with inlet and outlet connections tangential to the vessel shell. Vessel shell diameter to be minimum three times the nominal inlet/outlet pipe diameter.
 2. Provide steel eliminator with entering velocity not to exceed 4' per second at peak 6PM.
 3. Units shall be equipped with internal air eliminator bundle filling the entire vessel to suppress turbulence.
 4. Each eliminator shall have a separate venting chamber to prevent system contaminants from harming the venting mechanism
 5. Eliminators shall include a bottom connection for a cleaning blow down connection.
 6. Eliminator must be capable of removing 100% of the free air, 100% of the entrained air and 99.6% of the dissolved air in the system fluid.
- ~~2. Provide an internal stainless steel air collector tube with 5/32-inch diameter perforations and 63 percent open area designed to direct accumulated air to an external air vent via an NPT connection at top of unit.~~
- ~~3. Construct the unit with a removable galvanized steel system strainer with 3/16-inch diameter perforations and a free area of not less than five times the cross-sectional area of the connecting pipe. Provide a blow-down connection to facilitate routine cleaning of the strainer.~~
- ~~4. Manufacturer shall provide data sheet specifying air collection efficiency and pressure drop at rated flow.~~
- ~~5. Provide a Manufacturer's Data Report for Pressure Vessels, Form U-1 as required by the provisions of the ASME Boiler and Pressure Vessel Code for each air separator.~~

2.04 RELIEF VALVES

- A. Provide diaphragm operated safety relief valve, ASME labeled, for relieving pressure. Refer to Drawings for pressure rating of valve and relief setting. Discharge water shall be through NPT connection.
- B. Provide valve with a low blow down differential constructed of bronze or iron body. The valve seat and all moving parts exposed to fluid shall be of non-ferrous material.

2.05 SUCTION DIFFUSER

- A. Provide suction diffuser as indicated on the Drawings. Units shall consist of angle type body with straightening vanes and combination diffuser-strainer-orifice cylinder with 3/16-inch diameter openings. Provide a permanent magnet located within the flow stream and removable for cleaning. Equip the orifice cylinder with a start-up disposable fine mesh strainer. Design orifice cylinder to withstand pressure differential equal to pump shutoff head a free area equal to five times cross section area of pump suction opening. Straightening vanes shall extend the full length of the orifice cylinder and be replaceable. Provide unit with adjustable support foot to carry weight of suction piping.

2.06 EXPANSION TANKS

- A. Provide a replaceable bladder type hydro-pneumatic expansion tank especially designed for

use on the services specified. Construct the compression tank of welded steel and equip with a heavy-duty butyl rubber flexible bladder to maintain a separation between the system water and the air cushion. The system water shall be contained within the bladder. Provide with top inlet connection for all water systems. Each tank shall bear an appropriate ASME label for the following minimum working pressures and temperatures:

1. Building Chilled Water (Or Glycol): 125 pounds per square inch gauge – 100 degrees F.
 2. Building Closed Condenser Water System: 125 pounds per square inch gauge – 100 degrees F.
 3. Building Hot Water: 125 pounds per square inch gauge – 240 degrees F.
- B. The minimum total tank and bladder volume shall be as specified on the Drawings. Provide a factory initial charge of [] pounds per square inch gauge.
- C. Provide suitable structural and seismic support as required for each tank as indicated on the Drawings.
- D. Provide for each tank, lifting lugs, base ring, drains, charging connections, piping connections, and specialties as required for bladder replacement and as indicated on the Drawings. Provide one (1) bottle of nitrogen gas and manifold to be used to charge all tanks. Each tank shall have an ASME relief valve set at the appropriate pressure.
- E. Provide a UL listed pressure operated by a brass bourdon tube activating a mercury switch. This switch shall activate a low-pressure alarm as indicated in Section 23 09 00 - Building Management System (BMS). Mercoid Series DA31-153-7 or approved equal.
- F. Paint the outside of the tank with a shop coat of approved rust inhibiting primer after fabrication.

2.07 MANUAL AIR VENT

- A. Construct from short vertical section of 2-inch diameter maximum or line size pipe to form air chamber. Provide 1/8-inch brass needle valve at top of chamber.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Provide automatic air vents at high points of all piping and as required for removal of air from the system using 3/4-inch steel pipe suitable for the pressure service between the main pipe and inlet. Provide 3/8-inch OD hard drawn Type L copper tubing from vent outlet for overflow in case of defective action. Copper tubing shall run into a suitable drain. When vents are located above hung ceilings, connect all vent drains to a common drain main and pipe to nearest sink or floor drain. Provide 3/4-inch valve in the inlet line for servicing of automatic air vent. Manual vents may be substituted for automatic vents, at system high points, only as directed by the Architect and where readily accessible.
- B. Provide at each heat transfer element supplied with water, not less than one 1/2-inch manual air vent.
- C. Provide manual air vent valves in the piping connections to each hot water heating coil and each chilled water coil (both supply and return where not automatically vented). Provide soft temper copper tube pigtail or manual vents so that vent can be discharged into a bucket.
- D. Provide relief valves at expansion tanks, pressure tanks and as indicated. Install relief valves in upright position with discharge piped to nearest floor drain.

- E. System relief valve capacity shall equal makeup valve capacity. Equipment relief valve capacity shall exceed flow rating of connected equipment. Where one pipe vents several relief valves, cross section area shall equal sum of individual vent areas.
- F. Install suction diffusers on pump inlets with ample space for basket removal. Where pumps are mounted on inertia pads, suction diffuser will be supported with steel pipe section on inertia pad. All other installations, the suction diffuser shall be supported by steel pipe section on a neoprene pad 1-inch thick. Remove start-up strainer after start-up and pipe cleaning has been accepted by Owner.
- ~~G. Provide two glycol concentration analysis kits for on-site analysis of glycol system. After charging the system with glycol and circulating for minimum 30 minutes take glycol sample and send to glycol manufacturer for analysis.~~

END OF SECTION

SECTION 23 21 13

PIPING AND ACCESSORIES

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this section shall include, but is not limited to, the following:

1. Piping
2. Fittings
3. Jointing Materials
4. Unions and Couplings
5. Mechanically Coupled Pipe
6. Heat Tracing
7. Water Detection System
8. Welding and Jointing Procedures
9. Cleaning of Piping Systems
10. Testing of Piping Systems

1.02 REFERENCE STANDARDS

- A. American National Standards Institute (ANSI)
- B. American Society of Testing and Materials (ASTM)
- C. American Water Works Association (AWWA)
- D. American Society of Mechanical Engineers (ASME)

1.03 QUALITY ASSURANCE

- A. Welding materials and labor to conform to ASME Code and applicable state Labor Regulations.
- B. All welders shall be certified by ANSI B31.1.0-1986 "Standard Qualification Welding Procedures, Welders and Welding Operators" or "Qualification Tests" in Section IX, ASME Boiler and Pressure Vessel Code.
- C. Each length of pipe, fitting, trap, fixture or device used in any piping system shall be stamped or indelibly marked with type, weight, quality and manufacturer's name or mark.
- D. Water detection systems shall comply with all codes having jurisdiction. The manufacturer shall guarantee the system for one year from the date the system is accepted by the Owner. Contractor shall replace all equipment found to be defective during this period.

1.04 SUBMITTALS

- A. Submit the following for review:
 1. Schedule indicating the ASTM specification number of the pipe being proposed along with its type and grade and sufficient information to indicate the type and rating of fittings for each service.
 2. Submit shop drawings indicating anchoring details, anchor points, guide details, etc.
 3. Submit manufacturer's data for strainers and fittings.
 4. Submit dimensioned drawings locating pipe penetrations through walls, slabs and other structural elements, anchor and guide locations, etc.

5. Submit pipe expansion and flexibility calculations.
 6. Submit test reports on all systems tested. Tests required by authorities having jurisdiction over the work shall be submitted on appropriate forms to the satisfaction of such authorities.
- B. Heat Tracing: Equipment sizes, locations, performance data, installation details, wiring diagrams and controls. Manufacturer's latest published data for materials, equipment and installation.

~~C. Leak Detection System:~~

- ~~1. Manufacturer's literature and illustrated installation instructions.~~
- ~~2. Wiring diagrams and parts list.~~
- ~~3. Written description of sequence of operation.~~
- ~~4. A graphic display map mounted near the module shall be prepared, after completion of installation, from "as-built" drawings furnished by the installer. The map shall indicate the location of the cables; connectors; landmarks such as columns and walls; and changes of cable direction.~~

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Strainers:
1. Y-type and Basket: Mueller Steam Specialty, Spirax-Sarco, Bailey Div. Of CMB Industries, Zurn Industries, Victaulic Co. of America
 2. Handwheel Operated Type: Hellan Fluid Strainer, Eaton, Yale-Towne
 3. Tee Type Grooved End: Victaulic Co. of America
 4. Basket Type: Viking
- B. Welding Fittings: Hackney, Bonney Forge Foundry, (Weld-o-lets), Weldbend
- C. Mechanical Couplings and Fittings: Victaulic, Anvil International Gruvlok
- D. Dielectric Fittings:
1. Unions: Watts, Perfection, Central Plastics, EPCO, Zurn, Hart
 2. Flanges: Watts, Capital, Central Plastics, EPCO
 3. Flange Kits: Calpico, Central Plastics, Advanced Plastics
 4. Couplings: Calpico, Lochinvar
 5. Nipples: Perfection, Sioux Chief, Victaulic
- E. Flange Gaskets: John Crane, Garlock, Manville
- F. Pre-Insulated Pipe and Fittings: Ricwil, Rovanco
- G. Heat Tracing: Raychem Type XL, Thermon Type FLX, Nelson Electric Type LT
- H. Water Detection System: TraceTek TTC-ENC-9/TT1000, or approved equal
- I. Cleaning of Piping Systems: Use chemicals as recommended by the water treatment specialist engaged under Section 15890: Water Treatment
- J. Testing of Piping Systems: American Gas and Chemicals "Leak-Tee", Cosgille Scientific "Sho Gas", Flamort Chemical "Detect-A-Leak", Highside Chemicals "Leak Finder Foam"

- K. Plastic Pipe Fittings: J-M Ring Tight
- L. Double-Contained Pipe and Fittings: Flo Safe Systems, Insul-Tek, Orion Fittings, Rovanco, Thermacor Process, Ricwil

2.02 SCHEDULE OF PIPING SYSTEMS

| Service | Material | Type | Weight |
|--|----------|-----------------|---|
| Pumped condensate, boiler feed, steam | Steel | Black | Schedule 40 |
| Steam (over 15 pounds per square inch gauge, less than 3-inch), condensate return, boiler blowdown | Steel | Black | Schedule 80 |
| Hot water runouts (radiation, fan coils, VAV terminal units) | Copper | Type L | Hard |
| Chilled and condenser water, brine, glycol, hot water heating (under 250 degrees F), vapor vents, diesel engine exhaust, safety relief valve discharge | Steel | Black | Schedule 40, 0.375-inch wall for 12-inch and larger |
| Hot water heating (under 250 degrees F), chilled and condenser water runouts, brine, glycol | Copper | Type L | Hard |
| | | Type K (buried) | Soft |
| Equipment drains and overflows, condensate drains, atmospheric vents, make-up water | Steel | Galvanized | Schedule 40 |
| | Copper | Type L | Hard |
| Refrigerant | Copper | Type L | Hard, capped and nitrogen filled |
| Refer to specific Mechanical Division sections for services not listed above, e.g., domestic water - refer to Section 22 11 00- Domestic Water Systems | | | |

2.03 SCHEDULE OF PIPING FITTINGS

| Service | Size | Material | Type | Weight |
|---|--------------------|---|--|------------------------------|
| Steam below 15 pounds per square inch gauge | Up to 2-inch | Cast iron | Threaded | 125 pound |
| | 2½-inch to 10-inch | Steel | Welded | Standard |
| | 12-inch and up | Steel | Welded | 0.375 inch wall |
| Steam at 15 pounds per square inch gauge and above | Up to 2½-inch | Steel | Welded | Schedule 80 |
| | 3-inch to 8-inch | Steel | Welded | Standard |
| | 10-inch to 30-inch | Steel | Welded | 0.375 inch wall |
| Steam condensate, pumped condensate, vents, boiler feedwater and blowdown | Up to 2-inch | Cast iron | Threaded | 250 pound |
| | 2½-inch and larger | Steel | Welded | Schedule 80 |
| Chilled, condenser, heating hot water, glycol and brine solutions Up to ___ floor | Up to 2-inch | Cast iron | Threaded | 250 pound |
| | | Wrought copper | Solder | Standard |
| | 2½-inch to 10-inch | Steel | Welded, mechanical coupling | Standard |
| 12-inch and larger | Steel | Welded, mechanical coupling | Standard ASTM #A-53, Grade B | |
| Chilled, condenser, heating hot water, glycol and brine solutions Above ___ floor | Up to 2-inch | Cast iron | Threaded | 125 pound |
| | 2½-inch to 10-inch | Steel | Welded, Mechanical coupling | Standard |
| | 12-inch and larger | Steel | Welded, mechanical coupling | Standard ASTM #A-53, Grade B |
| Fan coil or terminal unit hot and chilled water runouts, coil condensate drains | All | Wrought copper | Solder | Standard |
| Controls compressed air | All | Wrought copper | Solder | Standard |
| | | | Victaulic grooved | Copper |
| Drains, vent and relief | All | Steel, galvanized | Threaded | Standard |
| Diesel engine exhaust pipe | All | Steel, black | Welded | Standard |
| Cooling tower filter piping | All | PVC with ultra violet light resistant paint | Solvent weld | Schedule 80 |
| Refrigerant | All | Wrought copper | Silver solder, copper-phosphorus alloy | Standard |
| Refer to specific Mechanical Division sections for services not listed above, e.g. domestic water - refer to Section 22 11 00: Domestic Water Systems | | | | |

| Service | Size | Material | Type | Weight |
|---------|------|----------|------|--------|
|---------|------|----------|------|--------|

2.04 PRESSURE PIPING AND FITTINGS

- A. Pressure piping shall conform to requirements of ANSI Safety Code for Pressure Piping, B31.1. Pressure ratings herein are steam, unless specifically designated as “WOG” (Water, Oil or Gas) or “WWP” (Water Working Pressure).
- B. Black Steel, Threaded, 2 inches and smaller: Schedule 40, ASTM A-120 or A-53:
 - 1. Cast iron banded fittings, ANSI B16.4, 125 pound class
 - 2. Malleable iron, ANSI B16.3, 150 pound class
- C. Black Steel, Welded, 2½ inches and larger: Schedule 40, ASTM A-53:
 - 1. Steel welding-neck fittings, ANSI B16.9
 - 2. Steel welding-neck flanges and flanged fittings, ANSI B16.5, 150 pound
- D. Black Steel, Grooved End: ASTM A-120 or A-53:
 - 1. Rolled groove – Schedule 10 to Schedule 40
 - 2. Machined groove – Schedule 40
 - 3. Fusion epoxy factory coating where indicated
 - 4. Fittings as herein after specified
- E. Galvanized Steel, Threaded: Schedule 40, ASTM A-120 or A-53:
 - 1. Fittings: Where weld fittings or mechanical grooved fittings are used, use only long radius elbows having a centerline radius of 1.5 pipe diameters:
 - a. Threaded, galvanized malleable iron fittings and ground-joint unions, ANSI B16.3, 150 pounds per square inch class, 2 inches and smaller
 - b. Threaded, cast iron, flanges and flanged fittings ANSI B16.1 125 pounds per square inch class, at values and piping specialties 2½ inches and larger
- F. Copper Tubing, ANSI H23.1:
 - 1. Wrought copper, solder joint fittings, ANSI B16.22, in sizes available with ANSI/AWS A5.8 or ASTM B 32 filler metals per Article 2.4, C
 - 2. Cast bronze solder-joint fittings, ANSI B16.18, only in sizes not available in wrought copper
 - 3. Cast bronze, threaded, ground-joint unions, ANSI B16.18, 2 inches and smaller
 - 4. Cast bronze, flanged unions, ANSI B16.24, 150 pounds per square inch class, 2½ inches and larger
 - 5. Copper tubing flared fittings: bronze castings for flared type joints, ANSI B-15.26
 - 6. Refrigerant piping shall be especially cleaned, dehydrated and capped by the piping manufacturer
 - 7. Medical gas piping shall be especially cleaned, dehydrated and capped in accordance with NFPA 99
 - 8. Victaulic grooved end copper fittings and couplings conforming to ASTM A-536/ASTM A-47
- G. Brass:
 - 1. Standard weight and red brass pipe, 85 percent copper, 15 percent zinc, ANSI H27.1
 - 2. 125 pounds per square inch threaded brass fittings, ANSI B16.15
- H. Cast Iron, Mechanical –Joints:

1. ANSI A21.6 (AWWA C106), ANSI A21.4 (AWWA C104)
 2. 150 pounds per square inch class
 3. Centrifugally cast, coated, cement lined
 4. Mechanical-joints, ANSI A21.11 (AWWA C111-53)
- I. Cast Iron, Flanged, ANSI A21.6 (AWWA C106), ANSI A21.4 (AWWA C104), 150 psi class:
1. Centrifugally cast, coated, cement lined
 2. Cast iron flanges and flanged fittings, ANSI B16.1, 125 pounds per square inch class
 3. Flanges integrally cast for long straight pipe runs
 4. Flanges may be threaded in areas requiring many fittings. Where field joints require close dimensional tolerance for make-up length of piping.
- J. Plastic pipe and fittings shall carry the National Sanitation Foundation Seal:
1. Threaded: Schedule 80
 2. Non-threaded except as noted: Schedule 40
 3. Unplasticized chlorinated polyvinyl chloride Type 1 (CPVC): ASTM D-2846
 4. Unplasticized polyvinyl chloride Type 1 (PVC) bell-end, AWWA C-900
 5. Unplasticized polyvinyl chloride Type 1 (PVC) Schedule 40 and 80: ASTM D-1785
 6. Polyethylene (PE) Schedule 40: ASTM D-2104
 7. Fittings:
 - a. Unplasticized Polyvinyl chloride Type 1 (PVC) pressure type:
 - (1) Socket type:
 - (a) ASTM D-2466, Schedule 40
 - (b) ASTM D-2467, Schedule 80
 - (2) Threaded type: ASTM D-2464, Schedule 80
 - (3) With National Sanitation Foundation Seal
 - b. Polyethylene (PE):
 - (1) Insert type: ASTM D-2609
 - (2) Butt fusion type: ASTM D-3261, ASTM D-2610, Schedule 40

~~K. Pre-Insulated Pipe and Fittings:~~

~~1. Insulation: Polyurethane foam with the following minimum characteristics:~~

- ~~a. Thermal Conductivity (K) Factor: 0.14~~
- ~~b. Density: 2 pounds per cubic foot~~
- ~~c. Closed Cell Content: 90-95 percent in conformance with MIL-I-24172 and ASTM C 591 completely filling the annular space between carrier pipe and jacketing. Minimum insulation thickness shall be in accordance with Table 1.~~

~~2. Jacketing Material: High-impact, seamless polyvinyl chloride (PVC) Class 12454-B compound conforming to ASTM D-1784, Type 1 Grade, 1-inch through 16-inch diameter. No FRP jacketing shall be allowed. Minimum jacket thickness shall be in accordance with Table 1. Jacketing for fittings, valves, etc. shall be of the same material, thickness and quality as used for piping, installed per manufacturer's recommendation.~~

TABLE 1 (all dimensions in inches)

| Minimum Pipe Size | Nominal Insulation Thickness | Jacket Size | Jacket Thickness |
|-------------------|------------------------------|-------------|------------------|
| 1½ | 1.47 | 4.5 | 0.085 |
| 2 | 1.51 | 5 | 0.085 |
| 2½ | 1.56 | 6 | 0.070 |
| 3 | 1.25 | 6 | 0.070 |
| 4 | 1.75 | 8 | 0.080 |
| 5 | 1.22 | 8 | 0.080 |
| 6 | 1.69 | 10 | 0.100 |
| 8 | 1.69 | 12 | 0.120 |
| 10 | 1.65 | 14 | 0.140 |
| 12 | 1.47 | 16 | 0.160 |
| 14 | 1.72 | 18 | 0.200 |

[OR]

3. ~~Jacketing Material: Provide 10-gauge black steel having all surfaces, both inside and outside, sandblasted to remove all foreign material, coated with an epoxy resin primer, coated on the inside with a single epoxy finish coat of not less than 6 mils, coated on the outside with two or more epoxy resin coats and glass cloth to a total thickness of not less than 20 mils. Oven cure each epoxy layer. Jacketing material shall be large enough to allow expansion and contraction of the system without having the insulation touch the outer conduit~~
4. ~~Expansion Loops and Elbows: Expansion loops or expansion elbows shall be furnished and enclosed in the same type of jacketing as those furnished for the standard section of the piping system. They shall be of a size to permit the inner pipe or pipes to move without damage to the insulation material. Provide flexible polyurethane insulation for all expansion loops and the first section of straight pipe upstream and downstream. All expansion loops or expansion elbows shall be prefabricated and shipped to the job site in as few pieces as possible (manufacturer's recommendations to govern). All inner pipe loops and expansion bends shall be cold sprung in the field as required.~~
5. ~~Weld fittings: All changes in direction shall be made with factory fabricated and preinsulated and jacketed welded fittings. Where tee branches are smaller than the mains they join, weld o-lets may be used. All weld fittings shall be long radius with the same wall thickness as adjacent piping.~~
6. ~~Anchors: Refer to Section 23-05-29 Supports, Hangers, Anchors and Sleeves. Insulate anchor per manufacturer's recommendations. Provide prefabricated plate anchors using 3/8 inch thick steel plate welded to the carrier pipe and sealed to the outer jacket.~~
 - a. ~~End Seals: Terminal ends of conduits inside manholes, pit, or building walls shall be equipped with end seals as recommended by conduit manufacturer.~~
 - b. ~~Carrier Pipe: Provide Schedule 40 ASTM A-53, Grade B, electric resistance welded black steel with beveled ends for field welded joints.~~

L. ~~Stainless Steel Piping:~~

1. ~~2 inch and smaller: ASTM A312 or A376, Schedule 40, seamless stainless steel, type 304 pipe with ASTM A182, Gr. F304, 3000 lb socket weld fittings~~
2. ~~2½ inch and larger: ASTM A312 or A376, Schedule 40, seamless stainless steel, Type 304 pipe with ASTM A403, Gr. WP304, butt-weld fittings~~
3. ~~Use 3000 lb. socket weld, stainless steel ground joint unions~~
4. ~~Use ASTM A182, Gr. F304, 150-pound flanges with 1/16-inch raised face, serrated face finish and weld neck pattern~~

2.05 JOINING MATERIALS

- A. Gaskets shall be rated ASME B16.21, nonmetallic, flat, asbestos-free full faced or flat ring type to suit flange facings. Selected from one of the following materials:
 - 1. General service, water, air, natural gas: 1/16-inch thick, non-asbestos. Crane Style 333 or approved equal
 - 2. PVC piping applications: 1/8-inch thick, Durometer 65 to 75; Goodrich "Koroseal", Grade 116 polyvinyl chloride or approved equal
 - 3. Hot water: Red rubber, ASTM D1330, 1/16-inch thick; Crane Style 555 or approved equal
 - 4. Gaskets shall be coated with thread lubricant when being installed
- B. Pipe threads shall be ANSI B2.1.
- C. Flange bolts and nuts shall be rated ASME B18.2.1, carbon steel.
- D. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer.
- E. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.
 - 1. 100 percent lead free, silver bearing solders equivalent to:
 - a. "Silverflo" by Canfield
 - b. "Stay-Safe Bridget" by J.W. Harris
 - 2. 95 percent tin and 5 percent antimony composition
- F. Brazing Filler Metals:
 - 1. General Duty: AWS A5.8, BcuP Series, copper-phosphorus alloys, unless otherwise indicated equivalent to:
 - a. "Stay- Silv 15" by J.W. Harris
 - b. "Sil Can 15" by Canfield
 - 2. Refrigerant Piping: AWS A5.8, BAg1, silver alloy for refrigerant piping, unless otherwise indicated equivalent to:
 - a. "Safety-Silv45" by J.W. Harris
 - b. "Sil Can 45" by Canfield
- G. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.06 UNIONS

- A. Steel piping 2 inches and smaller: ASTM A197/ANSI B16.3 malleable iron unions with brass seats. Use unions of a pressure class equal to or higher than that specified for the fittings of the respective piping service but not less than 250 pounds square inch, ground joint.
- B. Steel Piping 2 inches and larger: ASTM A181 or A105, Grade 1 hot forged steel flanges of threaded, welding neck, or slip-on pattern and of a pressure class compatible with that specified for valves, piping specialties and fittings of the respective piping service. Flanges smaller than 2½ inches may be used as required for connecting to equipment and piping specialties. Use raised face flanges ANSI B16.5 for mating with other raised face flanges on

equipment with flat ring or full-face gaskets. Use ANSI B16.1 flat face flanges with full-face gaskets for mating with other flat face flanges on equipment. Gasket material to be non-asbestos and suitable for pressures and temperatures of the piping system.

C. Copper Piping: Nibco No. 633

2.07 DIELECTRIC FITTINGS

A. Unions:

1. 1¼ inches and smaller: EPCO Model FX or approved equal:
 - a. 250 pounds per square inch WOG
 - b. Provide standard gaskets for plumbing, high temperature gaskets for heating
 - c. Female pipe thread by solder end connections, non-asbestos gaskets, having a minimum pressure rating of 250 psig at not less than the design operating temperature of the fluid being conveyed
 - d. Clearflow dielectric waterways
2. 1½ inches and larger: EPCO Model X or approved equal:
 - a. Brass half-union, ANSI B16.1, 175 pounds per square inch WOG
 - b. Clearflow dielectric waterways
 - c. Steel weld neck by copper solder joint end connections, non-asbestos gaskets, having a minimum pressure rating of 125 psig at not less than the design operating temperature of the fluid being conveyed

B. Insulating Flanges:

1. Dielectric-Flange Kits: Provide companion-flange assembly for field assembly. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.
2. Provide separate companion flanges and steel bolts and nuts, 150 or 300 psig minimum working pressure where required to suit system pressures.
3. 2 inches and smaller: Walter Vallett Company, V line or approved equal.
4. 2½ inches and larger: Brass half-union, ANSI B16.1, 175 pounds per square inch WOG, EPCO Model X or approved equal.

C. Couplings: Provide galvanized-steel coupling with inert and noncorrosive, thermoplastic lining, threaded ends and 300-psig minimum working pressure at 225 degrees F.

D. Nipples: Provide electroplated steel nipple with inert and noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and 300-psig minimum working pressure at 225 degrees F.

2.08 MECHANICALLY COUPLED GROOVED END PIPING SYSTEM

A. Provide mechanically coupled grooved end fittings and pipe similar to Victaulic roll grooved products manufactured under ISO 9001 certification.

B. The following services may use mechanical grooved pipe connections within the building in mechanical spaces and above accessible ceilings. Mechanical shafts and chases are not considered accessible.

1. Heating hot water
2. Chilled water
3. Condenser water

C. Piping Components:

1. Grooved couplings shall consist of two or more pieces of ductile or malleable iron. Coupling gaskets shall be a synthetic rubber gasket with a central cavity pressure responsive design. Coupling bolts and nuts shall be heat-treated carbon steel, trackhead conforming to physical properties of ASTM A-183. Use Style 77 couplings for all joints within 10 feet of riser connections. Grooved fittings, couplings, valves and gaskets must be manufactured under ISO 9001. Reducing couplings are not acceptable.
2. Make full size branch connections for piping 2½ inches and larger with manufactured grooved end tees. Branch connections for less than full size shall be made with hole cut products. Style 920 or Style 921 branch connections with locating collar engaging into hole or Style 72 outlet coupling used to joint grooved pipe and to create a branch connection. Provide gaskets for branch connection using Grade "E" EPDM Compound with working temperature of minus 30 degrees to 230 degrees F. Gaskets must be ISO 9001 certified. Gaskets shall be provided by the same manufacturer that provides the coupling housing.
3. Provide flanges for all connections to flanged components as follows:
 - a. Style 741 (2 inches or larger) for connection to ANSI class 125 and 150 flanged components
 - b. Style 743 (2 through 12 inches) for connection to Class 300 flanged components
4. Provide full-flow cast fittings, manufactured under ISO 9001 with grooves to accept grooved end couplings as recommended by the manufacturer:
 - a. Standard Fittings: Cast of ductile iron conforming to ASTM A-536 (Grade 65-45-12), painted with a rust inhibiting modified vinyl alkyd enamel or hot-dip galvanized to ASTM A-153 or zinc electroplated to ASTM B-633, as required
 - b. Standard Steel Elbow Fittings (14-24 inches): Forged steel conforming to ASTM A-106, Grade B (0.375 inch wall) painted with rust inhibiting modified vinyl alkyd enamel or hot-dip galvanized to ASTM A-153
 - c. Standard Segmentally Welded Fittings: Factory fabricated, by fitting manufacturer, of carbon and steel pipe as follows: ¾ inches - 4 inches conforming to ASTM A-53, Type F; 5 inches - 6 inches Schedule 30 conforming to ASTM A-53, Type E or S, Grade B; 8 inches - 12 inches Schedule 30 conforming to ASTM A-53, Type E or S, Grade B, painted with rust inhibiting modified vinyl alkyd enamel or hot-dip galvanized ASTM A-153, as required.
 - d. Mechanical-Tee: Style 920 fittings with malleable iron housings may be used for up to 2-inch outlet size.

2.09 STRAINERS

- A. Provide screwed ends up to 2-inch size, flanged 2½-inch and larger.
- B. Body:
 1. Up to 150 pounds per square inch: Y-type; cast iron body; bolted or threaded screen retainer tapped for a blowoff valve; threaded body in sizes through 2-inch and rated at not less than 175 psi WOG; flanged body in sizes over 2-inch and rated at not less than 125 psi WOG at 240 degrees F. Cast iron body with clamped cover, tapped for a blowoff valve; 125 psig flanged body for 2½-inch and larger.
 2. Up to 150 pounds square inch, basket type: Cast iron body with clamped cover; body tapped for a blowoff valve; 125 psig flanged body for 2½-inch and larger.
 3. Over 150 pounds per square inch: Y type; cast iron or cast steel body; stainless steel screens; bolted or threaded screen retainer tapped for a blowoff valve;

- threaded or socket weld body in sizes through 2-inch and rated at not less than 300 psi WOG at 150 degrees F; flanged or butt weld body in sizes over 2-inch and rated at not less than 300 psi WOG at 150 degrees F.
4. Steam service up to 100 psig: Y type; steel body, bolted or threaded screen retainer tapped for a blowoff valve; threaded or flanged in sizes through 2-inch; flanged in sizes over 2-inch; rated at not less than 250 psi at 400 degrees F.
 5. Steam service over 100 psig: Y type; cast steel or forged steel body, bolted or threaded screen retainer tapped for a blowoff valve; threaded, socket weld, butt weld, or flanged end connections in all sizes; suitable for steam service at 600 psig.
- C. Strainer screen shall be 316 stainless steel or monel, reinforced, with free area not less than 2½ times inlet area.
1. Perforations:
 - a. Water:
 - (1) Up to 2-inch: 1/32 inches
 - (2) 2½-inch to 8 inch: 1/8 inches
 - (3) 10-inch and larger: 5/32 inches
 - b. Steam and Condensate:
 - (1) To 2-inch: 1/64 inches
 - (2) 2½-inch to 4-inch: 1/32 inches
 - (3) 5-inch and up: 3/64 inches
 2. Magnets, except for handwheel operated type:
 - a. Water strainers:
 - (1) All 8-inch and larger
 - (2) Each pump suction
 - b. Provide continuous magnetic field around entire circumference of screen.
 - c. Removable cast Alnico No. 5 channel magnets or approved baskets constructed of magnetic alloy.
 - d. Secure magnets with stainless steel retaining lugs and threaded rods.
- D. Y-Type:
1. Screwed: Faced cap, straight thread and gasket, Muessco No. 11M or approved equal
 2. Flanged: Bolted cover, Muessco No. 751 or No. 752 or approved equal
- E. Basket Type: Bolted cover, bottom drain connection, Muessco No. 165, or approved equal.
- F. Duplex type shall be used for fuel oil basket strainer:
1. Up to 6-inch: Provide cast iron body with bolted cover, bronze plug valve and integral mechanism to permit servicing without interrupting flow; Zurn Series 560FBS or approved equal.
 2. 8-inch and larger: Gate type, iron body with monel basket and integral mechanism to permit servicing without interrupting flow; Zurn Series 570, or approved equal
- G. Grooved End Type: Wye type grooved joint for vertical or horizontal installation with blow-off plug.

2.10 HEAT TRACING

- A. Heat tracing cable shall consist of two (2) 16 AWG tinned copper bus wires, embedded in parallel, in a self-regulating semi-conductive core that varies its power output to respond to temperature along its length.
- B. Heater to be capable of being crossed over itself without overheating and of being cut to length in the field.
- C. Cover cable with a cross-linked modified polyolefin dielectric jacket. Protect cable with a tinned copper braid. Cable shall be approved for use without ground fault protection of the electric branch circuit.
- D. Heat tracing cable shall operate on line voltage of ~~[277]~~~~[208]~~~~[230]~~~~[120]~~ volts without the use of transformers.
- E. Manufacturer shall provide power connection, end seals, splice and tee kits for a complete Underwriters' Laboratories listed system. Heat tracing cable shall be sized using manufacturer's standard procedure and shall maintain fluid within pipe at 40 degrees F when outside temperature is minus 10 degrees F.
- F. Provide a line voltage thermostat for on-off control of heat tracing cable by sensing ambient temperature at the traced pipe and turn heat tracing on when outside temperature is below 35 degrees F and turn the heat tracing off when outside temperature is above 35 degrees F.
- G. Provide and install manufacturer's recommended glass cloth adhesive tape and "Electrically Heat-Traced Pipe" labels at maximum of 30-foot centers.
- H. Each circuit shall be protected with a 30 milliamp ground-fault protection device.
- I. Required output rating is in watts per foot at 50 degrees F, based on 1-inch fiberglass insulation on metal piping. Minimum Ambient minus 10 degrees F
 - 1. 4-inch pipe or less: 5 watts per foot
 - 2. 6-inch pipe: 8 watts per foot
 - 3. 8- and 10-inch pipe: 2 strips at 5 watts per foot each
 - 4. 12- and 14-inch pipe: 2 strips at 8 watts per foot each
 - 5. 16- to 24-inch pipe: 3 strips at 8 watts per foot each

2.11 WATER DETECTION SYSTEM

- A. Provide a complete electronic cable system that detects the presence of water at all points along the cables. The sensing cable shall be constructed such that no metallic parts are exposed to the environment. The installation kit shall include all system components required for a typical installation.
- B. Cable driver modules:
 - 1. Monitor one length of water sensing cable up to 500 feet long. The cable driver module shall indicate that water has been detected by activating an alarm LED and actuating the output signal. The "alarm" LED shall remain on as long as the sensing cable is wet. The module shall automatically reset when the cable is dried or replaced.
 - 2. Monitor the cable for continuity. Damage to the sensing cable or leader cable shall cause the cable driver module to activate, a continuity LED, and actuate a separate output signal. LED's shall indicate "power" (green), "alarm" (red), and "continuity" (yellow).
 - 3. Modules shall be powered by 12 to 24 volts AC or 15 to 24 volts DC. The module shall have two double-pole/double-throw relays with 3 amp rating for leak detection

and one single-pole/single-throw relay with 3 amp rating for loss of power or a break in the sensor cable.

4. Modules shall be supplied installed in a Hoffman (or equal), NEMA-1 enclosure. The enclosure shall be supplied with one sensor cable driver module. Terminal strips, pre-wired from each cable driver module shall include:
 - a. Incoming power (2 terminals).
 - b. One common trouble alarm signal for the leak relay and trouble relay contacts of each module (2 terminals for connection to BMS or remote annunciator panel).
 - c. Sensor cable connections (4 terminals/module).
5. Mount at the location specified or shown on the drawing. Four-conductor, 18-AWG, plenum rated jumper cable shall be installed from each cable driver module to each section of sensor cable.

C. Water sensing cable shall detect the presence of water and pinpoint its location:

1. Cable shall consist of four (4) wires: two (2) sensor wires, a continuity wire, and a return wire. All four (4) wires shall be coated or insulated with fluoropolymer and wound helically around a central fluoropolymer core. Cables using exposed metal or non-fluoropolymer construction shall not be acceptable.
2. Minimum breaking strength including connectors: 70 pounds per ASTM D-638.
3. Abrasion resistance: greater than 65 cycles per UL 719.
4. Cables shall be capable of accommodating any number of branches using branch connectors. Provide distributed sensing with the ability to detect the location of water at any point along the length of the cable.
5. The cable shall be flexible, carry less than 24 volt DC under normal operating conditions and available in modular lengths of 3, 10, 25, and 50 feet with factory installed male/female connectors.
6. Contact by the sensing cable with any metallic equipment under the floor, such as drip pans, tile supports or conduit, shall not alarm the system.
7. The cable shall pass UL 910, Test Method for Fire and Smoke Characteristics of Electrical and Optical-Fiber Cables Used in Air Handling Spaces, and shall be plenum rated per NEC 725-2(b).

D. Standard accessories shall include modular end terminations, modular leader cables, caution tags, and hold down clips.

2.12 UNDERGROUND PIPE WRAP

- A. Use a flexible polymer film with a coal tar and synthetic elastomeric coating of 36 mil thickness and dielectric strength exceeding 12 kilovolts. Use a compatible primer below the polymer film.

PART 3 – EXECUTION

3.01 APPLICATION

- A. In addition to applicable portions of the Part 3, refer to the following sections for installation, testing and cleaning requirements for specific piping systems.
 1. Section 15485 - Medical Gas Systems; Oxygen, Nitrous Oxide, Nitrogen, Medical Compressed Air, Medical Vacuum, Carbon Dioxide, Waste Anaesthetic Gas Disposal
 2. Section 21 13 19 - Fire Protection Systems
 3. Section 21 20 00 - Fire Suppression Systems
 4. Section 22 11 00 - Domestic Water Systems; Domestic Cold, Hot Water, Hot Water

- Circulating Piping Systems
- 5. Section 22 11 30 - Reclaimed Water Systems
- 6. Section 22 13 00 - Drainage Systems; Waste, Vent and Storm Water
- 7. Section 22 61 13 - Propane Gas Systems; Propane Gas
- 8. Section 22 62 00 - Vacuum System; Laboratory Vacuum
- 9. Section 22 63 13 - Natural Gas Systems; Natural Gas
- 10. Section 22 63 14 - Nitrogen Systems; Liquid Nitrogen, Nitrogen Gas
- 11. Section 22 63 15 - Laboratory Gas Cylinder Systems; Laboratory Gases
- 12. Section 22 67 00 - Pure Water Systems
- 13. Section 23 05 29 - Supports, Hangers, Anchors and Sleeves
- 14. Section 23 13 13 - Below Ground Fuel Oil Storage Tank and Accessories
- 15. Section 23 13 23 - Above Ground Fuel Oil Storage Tank and Accessories

3.02 INSTALLATION

A. General:

1. Except as otherwise indicated protect piping as specified below:
 - a. Allowance for thermal expansion and contraction shall be provided for piping passing through a wall, floor, ceiling or partition by wrapping with an approved tape or pipe insulation, or by installing through an appropriately sized sleeve to allow for thermal movement.
 - b. Protection against abrasion shall be provided where piping comes in contact with other building members by wrapping with an approved tape, pipe insulation or otherwise suitable method of isolation.
 - c. No ashes, cinders, refuse, stones, boulders or other materials that can damage or break the piping or promote corrosive action shall be used in backfilling any trench or excavation in which piping is installed.
2. Install piping at indicated slope free of sags, bends, and kinks. Install components having pressure rating equal to or greater than system operating pressure. Support all piping per Section 23 05 29 - Supports, Hangers, Anchors and Sleeves.
3. Brace all piping per Section 23 05 48 - Vibration Isolation and Seismic Restraints.
4. Clean off scale, rust and dirt, inside and outside, before assembly. Remove welding slag or other foreign material from piping.
5. Install (at traps, humidifiers, instruments, etc., and wherever else directed) approved unions, to permit easy connection and disconnection.
6. Make riser branches and other offsets with 4-elbow swings including copper risers and branches.
7. After systems are in operation, if coils do not circulate quickly and noiselessly (due to trapped or airbound connections), make all necessary corrections to the work including altering finished construction and refinishing without additional cost.
8. Make piping connections to coils, [humidifier distribution manifolds] and equipment with offsets provided with screwed or flanged unions so arranged that the equipment can be serviced or removed without dismantling the piping. Do not screw unions directly to coil header [and humidifier] piping connections.
9. Use main sized saddle type branch connections for directly connecting branch lines to main piping lines in steel piping if main is at least one pipe size larger than the branch for up to 6-inch main and if main is at least two pipe sizes larger than branch for 8-inch and larger main. Do not project branch pipes inside the main pipe.
10. Cap all openings in pipes during progress of the work.
11. Do not connect bottom of pipe risers until riser is complete. Rod or tap to clear loose material before making bottom connection.
12. Correct leaks in piping immediately using new materials. Leak-sealing compounds or peening is not permitted.
13. Install drains throughout the systems to permit complete drainage.
14. Not acceptable: mitered ells, bullhead tees, notched tees, bushings on threaded piping.

15. Do not allow any other subcontractor (electrical, telephone company, BMS, elevator, etc.) to electrically ground to any mechanical system.
16. Install cast-iron sleeve with water stop and mechanical sleeve seal at each service pipe penetration through foundation wall. Select number of interlocking rubber links required to make installation watertight. Encase underground piping with polyethylene film according to ASTM A 674 or AWWA C105.

B. Arrangement:

1. Except for large scale details, piping is diagrammatically indicated. Install generally as shown.
2. Do not scale Drawings for exact location of piping.
3. Install piping to best suit field conditions and coordinate with other trades.
4. Piping arrangement: Arrange piping along walls in horizontal groups in an organized, orderly, well executed manner. Each group shall be in one plane if possible. Maintain required slope.
5. Do not sleeve structural members without consent of Architect.
6. Maintain 1-inch clearance from adjacent work, including insulation, except as noted or approved.
7. Install piping concealed above as high as possible above ceilings or in walls unless otherwise indicated. Install all piping parallel to building walls and ceilings and at heights that do not obstruct any portion of a window, doorway, stairway, or passageway. Where interferences develop in the field, offset or reroute piping as required to clear such interferences. In all cases, consult drawings for exact location of pipe spaces, ceiling heights, door and window openings, or other architectural details before installing piping.

C. Expansion, Contraction and Bending:

1. Install piping with provisions for expansion and contraction. Provide expansion loops, swing joints, anchors and/or expansion joints where indicated or otherwise required so that piping may expand and contract without damage to itself, equipment, or building.
2. Do not spring or force piping during installation.
3. Do not bend piping without use of pipe bending machine.
4. Refer to Section 23 05 16 - Expansion Compensation.

D. Sloping, Air Venting and Draining:

1. Slope piping as indicated, true to line and grade, and free of traps and air pockets.
2. Unless indicated otherwise, slope piping in direction of flow as follows:

| Service | Inclination in Direction of Flow | Slope |
|-----------------------------------|----------------------------------|--------------------|
| Steam | Down | 1 inch per 40 feet |
| Steam Condensate | Down | 1 inch per 20 feet |
| Heating Water, Condenser Water | Up | 1 inch per 40 feet |
| Chilled Water, Glycol | Up | 1 inch per 40 feet |
| Condensate Drain | Down | 1/8 inch per foot |

3. Slope up-feed steam and condensate runouts up toward equipment 1/2 inch per foot.
4. Slope air line up 1 inch per 10 feet towards storage tank.
5. Make changes in direction for storm piping using appropriate branches, bends, and long-sweep bends. Do not change direction of flow more than 90 degrees F. Use proper size of standard increasers and reducers if pipes of different sizes are connected. Reducing size of drainage piping in direction of flow is prohibited.
6. Lay buried building drain piping beginning at low point of each system. Install true to

grades and alignment indicated, with unbroken continuity of invert. Place hub ends of piping upstream. Install required gaskets according to manufacturer's written instructions for use of lubricants, cements, and other installation requirements. Maintain swab in piping and pull past each joint as completed.

7. Reducers:

a. Eccentric:

- (1) In horizontal steam and condensate piping, bottom side flat
- (2) Heating water and chilled water piping, top side flat
- (3) Between water piping and pump suction, top side flat

b. Concentric:

- (1) In vertical piping
- (2) May be used as increasers in horizontal piping

8. Connect steam and condensate branch piping to top of mains.

9. Connect heating water and chilled water branch piping to bottom of mains.

10. Provide drain valves and hose adapters at all low points in piping.

11. Provide drain valves for float type controllers.

12. Provide manual air vents at all high points in condenser water, heating water and chilled water piping:

- a. ¼-inch copper tube
- b. Discharge vented water into nearest janitor's sink or floor drain
- c. If no fixture is near provide 180-degree bend to discharge into portable container

E. Strainers:

1. Install at following locations:

- a. Ahead of pump suctions
- b. Ahead of control and regulating valves
- c. Ahead of steam traps
- d. Elsewhere as indicated on Drawings

2. In water service, up to 250 degrees F maximum; and compressed air:

- a. Install globe valve for blow-off with full outlet size and same pressure rating as piping system.
- b. Hose-end fittings are acceptable for water service only.

3. In steam and high temperature water service, provide a threaded, plugged blow-off opening, unless otherwise indicated on Drawings.

F. Piping Specialties:

1. Locate thermometers and gauges to permit observation by personnel standing on floor.
2. Provide instrument cocks at pressure gauges.
3. Provide continuous lengths of straight runs of piping upstream and downstream from [venturis] [balancing devices] as recommended by manufacturer. No joints, welds, fittings or taps are permitted in the straight runs.

G. Copper:

1. Crimping of copper tubing prohibited.
 2. Isolate copper pipe and tubing from contact with ferrous materials.
 3. For branch drops and rises to plumbing fixtures, anchor branch to wall with drop-ear ell or tee.
 4. Remove all slivers and burrs remaining from the cutting operation by reaming and filing both pipe surfaces. Clean fitting and tube with emery cloth or sandpaper. Remove residue from the cleaning operation, apply flux, and assemble joint. Use 95-5 solder or brazing to secure joint as specified for the specific piping service.
- H. Coatings: Reapply mastic coating on buried piping, after installation, to surfaces from which coating has been removed or scraped.
- I. Care of Floors:
1. Do not set pipe vises or threading machines on unprotected concrete floors.
 2. Cover floor when making plumbing connections to avoid staining floors with oil, white or red lead or other substances. Bear cost of removing any stains.
- J. Heat Trace Cable:
1. Provide heat trace cable for piping systems, where indicated on drawings.
 2. Install cable and components per manufacturer's instructions.
 3. Apply "Electric Traced" labels to heat trace cables covered in insulation.
- K. Water Detection System:
1. Provide heat trace cable for piping systems, where indicated on drawings.
 2. Install detection components per manufacturer's instructions.

3.03 SYSTEMS INSTALLATION

- A. Steam and Condensate:
1. Install drains, consisting of a tee fitting, ¾-inch ball valve, and short ¾-inch threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.
 2. Unless otherwise indicated, install branch connections to steam mains using 45-degree fittings in main pipe, with the takeoff coming out the top of the main pipe. Use of 90-degree tee fittings is permissible if 45-degree fittings are impractical. If length of branch takeoff is less than 10 feet, pitch branch line down toward mains at a 0.4 percent grade.
 3. Install unions in piping 2-inch and smaller adjacent to each valve, at final connections to each piece of equipment, and elsewhere as indicated.
 4. Install flanges in piping 2½ and larger at final connections of each piece of equipment and elsewhere as indicated.
 5. Install strainers on supply side of each control valve, pressure-reducing valve, solenoid valve, traps, and elsewhere as indicated. Install ¾-inch nipple and ball valve in blowdown connection of strainers 2 inches and larger. Match size of strainer blowoff connection for strainers smaller than 2 inches.
 6. Anchor piping for proper direction of expansion and contraction.
 7. Unless otherwise indicated, install gate valve, strainer, and union upstream from trap; install union, check valve, and gate valve downstream from trap. Provide steam trap assembly at:
 - a. Low points of steam piping
 - b. Bottom of steam risers and drops
 - c. Each piece of equipment, separately, whether or not indicated on Drawings
 - d. Provide rise and drip with trap every 300 feet maximum where pipe is pitched down in direction of steam flow and a maximum of 150 feet where

pipe is pitched up in direction of steam flow.

8. Install steam pressure reducing valves and stations according to metering [University] [Utility Company] [Owner] [Local Jurisdiction] standards.
9. Pipe flashed high and medium pressure steam to flash tank.
10. Install automatic control valves for the domestic hot water heaters.
11. Install steam pressure reducing valves (PRVs) furnished under other Divisions of the Specifications for each item of kitchen and laundry equipment requiring steam supply.
12. Provide drip trap assembly at low points, points where condensate may back up in front of control valves and natural drainage points such as ends of mains, bottoms of risers, and ahead of pressure regulators, control valves, isolation valves, pipe bends, and expansion joints. Run condensate lines from traps to nearest condensate receiver. Where condensate lines form a trap, provide vent loop over the trapped section.
 - a. Size drip legs at vertical risers same size as pipe and extend beyond rise. Size drip legs at other locations same diameter as main. In steam mains 6-inch and larger, dirt leg size can be reduced, but to no less than 4-inch.
 - b. Install gate valve at drip legs, dirt pockets, and strainer blowdowns to allow removal of dirt and scale.
 - c. Install steam traps close to drip legs.
13. Pitch condensate piping down toward flash tank. If more than one condensate pipe discharges into flash tank, install a swing check valve in each line. Install thermostatic air vent at top of tank. Install inverted bucket or float and thermostatic trap at low-pressure condensate outlet, sized for three times the condensate load. Install safety valve at tank top. Install pressure gage, gate valve, and swing check valve on low-pressure (flash) steam outlet.
14. Vent steam relief piping to atmosphere at locations approved by the Architect. Refer to exhaust head detail. Steam vents from flash tanks and condensate receivers shall be vented independently of pressure relief vents.

B. Pre-Insulated Pipe and Fittings:

1. The installation shall be made in accordance with plans and specifications, and manufacturer's installation instructions. Provide a manufacturer's field service instructor on site to train the Contractor in all phases of installation.
2. Earth or sand backfill shall be hand placed and hand tamped compactly in place to assure a stable surface. No rock shall be used in the first foot of backfill. The 30 inches from top of pipe to grade shall be compacted fill meeting H-20 Highway Loading.
3. After all anchor blocks are poured and cured, the inner pipes of this system shall be tested hydrostatically to 150 pounds per square inch for four hours of duration. If a leak is found, it shall be repaired and the test repeated.
4. Do not locate pipe joints under roadways or areas subject to motorized vehicular traffic.

C. Refrigerant:

1. Clean, dehydrate, and cap refrigerant piping. Ensure that entire system is clean and dry during installation. Clean tubing by means of swab saturated in methyl alcohol. Draw through tubing as many times as necessary to thoroughly clean and dry interior of tubing and to eliminate formation of copper oxide.
2. Before refrigerant lines are silver brazed, flush all air from tubing and pass slow-running stream of dry nitrogen through system during brazing process. Purge lines completely and maintain nitrogen flow at steady rate of not less than three cubic feet per hour.
3. Refrigeration piping shall be installed in accordance with the requirements of ARI,

- ASHRAE and ASTM.
4. All solder joints shall be ASTM Grade 4 or 5 and have a melting point of approximately 1250 degrees F. Solder impurities shall not exceed 0.15 percent. Tubing shall be new and delivered to the job site with the original mill end caps in place. Clean and polish all joints before soldering. Avoid prolonged heating and burning during soldering. Purge all lines with nitrogen during soldering. Provide manual shut-off and check valves as required. After brazing, interior of refrigerant lines must be clean and bright.
 5. Comply with EPA Section 608 requirements: Prohibition of Venting and Regulation of CFC Requirements. No refrigerant shall be vented directly to the atmosphere except that which may escape through leaks in the system during leak testing. During evacuation procedures, use equipment designed to recover and allow recycling of the refrigerant.
 6. Install core in filter dryer after leak test but before evacuation.
 7. Evacuate refrigerant system with vacuum pump until temperature of 35 degrees F is indicated on vacuum dehydration indicator.
 8. During evacuation, apply heat to pockets, elbows, and low spots in piping.
 9. Maintain vacuum on system for minimum of 5 hours after closing valve between vacuum pump and system.
 10. Break vacuum with refrigerant gas, allow pressure to build up to 2 psi.
 11. Complete charging of system, using new filter dryer core in charging line. Provide full operating charge.
 12. After completion of the leak test, evacuate the system with a vacuum pump to an absolute pressure not exceeding 1500 microns while the system ambient temperature is above 60 degrees F. Break the vacuum to 2 psig with the refrigerant to be used in the system. Repeat the evacuation process, again breaking the vacuum with refrigerant. Install a drier of the required size in the liquid line, open the compressor suction and discharge valves, and evacuate to an absolute pressure not exceeding 500 microns. Leave the vacuum pump running for not less than two hours without interruption. Raise the system pressure to 2 psig with refrigerant and remove the vacuum pump.
 13. Charge refrigerant directly from original drums through a combination filter-drier. Each drier may be used for a maximum of three cylinders of refrigerant and then must be replaced with a fresh drier. Charge the system by means of a charging fitting in the liquid line. Weigh the refrigerant drum before charging so that an accurate record can be kept of the weight of refrigerant put in the system. If refrigerant is added to the system through the suction side of the compressor, charge in vapor form only.
 14. Install branch tie-in lines to parallel compressors equal length, and pipe identically and symmetrically.
 15. Slope refrigerant piping as follows:
 - a. Install horizontal hot gas discharge piping with ½-inch per 10 feet downward slope away from the compressor.
 - b. Install horizontal suction lines with ½-inch per 10 feet downward slope to the compressor, with no long traps or dead ends that may cause oil to separate from the suction gas and return to the compressor in damaging slugs.
 - c. Liquid lines may be installed level.
 16. Install traps and double risers where indicated, and where required to entrain oil in vertical runs.
 17. Install strainers immediately ahead of each expansion valve, solenoid valve, hot gas bypass valve, compressor suction valve, and as required to protect refrigerant piping system components.
 18. Install moisture/liquid indicators in liquid lines between filter/driers and thermostatic expansion valves and in liquid line to receiver.
 19. Install moisture/liquid indicators in lines larger than 2-1/8 inch OD, using a bypass line.
 20. Install unions to allow removal of solenoid valves, pressure regulating valves,

- expansion valves, and at connections to compressors and evaporators.
21. Install flexible connectors at the inlet and discharge connection of compressors.
 22. Verify actual evaporator applications and operating conditions, and adjust thermostatic expansion valve to obtain proper evaporator superheat requirements. Adjust controls and safeties. Replace damaged or malfunctioning controls and equipment with new materials and products.

D. Underground Pipe Wrap:

1. Provide for all underground metallic piping that is not encased in a non-metallic conduit and for underground metallic gas conduit.
2. Remove all dirt and other foreign material from exterior of pipe. Apply primer as recommended by the manufacturer.
3. Use a spiral wrap process for applying tape to the pipe. Repair any breaks in the tape coating caused by the installation process.

E. Underground Piping:

1. Install piping where indicated and according to manufacturer's instructions.
2. Install closures at points of field joints between straight units or fabricated fittings by welding them centrally over conduit ends between such adjacent units.
3. After welding, conduct a 25 psig air pressure test on the outer casing and examine for leaks with a soap solution.
4. Repair any leaks and retest until the system is airtight at 25 psig air pressure for a two hour period.
5. Clean closures of all welding slag, burned coating, mud, etc. by wire brushing.
6. Finish coat in accordance with the system manufacturer's instructions, using materials supplied. Final outside coating to be subjected to a spark test and be capable of maintaining dielectric strength at 5,000 volts.
7. Contractor shall furnish all necessary equipment and labor to perform the spark test and the air test, including air compressor, gauges, conduit caps, temporary pipe and connections, etc., and complete the tests to the satisfaction of the Architect.

F. Heat Trace Cable:

1. Cable shall be secured to piping with cable ties or fiberglass tape.
2. Install heater cable linearly along the pipe's lower quadrants after pipe has been successfully pressure tested.
3. Wrap extra cable around fittings and valves as required to offset heat loss at these areas.

G. Water Leak Detection System:

1. All components shall be installed in accordance with manufacturer's installation instructions. The installer shall be responsible for providing a clean and functional system with supervision and training available from a distributor or other personnel authorized by manufacturer.
2. The sensing cable shall be installed after all piping, air conditioning, raised flooring, and other mechanical work is completed. The subfloor shall be cleaned prior to installing the sensing cable.
3. Care shall be taken during installation of the sensing cable to avoid contact with potential contaminants, such as puddles or solder flux.
4. The cable shall be fastened securely to the surface of the floor slab with hold down clips together with construction mastic plastic adhesive every 4 feet.
5. The system shall be commissioned upon completion of the installation by personnel in accordance with manufacturers instructions.

3.04 PIPE JOINTING

A. Fittings:

1. Provide standard, manufactured fittings in all cases.
2. Prohibited fittings:
 - a. Field fabricated
 - b. Bushings on pressure piping
 - c. Clamp-on branch connections
3. Dielectric separation:
 - a. Provide insulating couplings or dielectric fittings at all connections or metal-to-metal contact of ferrous materials to non-ferrous materials.
 - b. Locations shall be accessible. Coordinate with General Contractor.
4. Branch connections, steel piping:
 - a. Equal to main and to two pipe sizes smaller: weld tees, same weight as piping.
 - b. Three or more pipe sizes smaller than main, but 2½ inches and larger: Bonney Weld-o-lets.
 - c. To two inches and smaller: Bonney Weld-o-lets, Thread-o-lets, threaded Nip-o-lets, or steel couplings.

B. Unions: Provide unions or flanges to render all items in systems easily removable, including:

1. Valves
2. Piping specialties
3. Both sides of pumps and equipment
4. Where indicated on the Drawings

C. Pipe Ends: Perform pipe cutting and end preparation to result in clean ends with full inside diameter. Grind and ream ends of pipe and tube and remove burrs to restore full inside diameter.

D. Nipples: Provide extra heavy pipe for nipples where unthreaded portion is less than 1½ inches long. Close nipples not permitted.

E. Threaded Joints: Ream threaded pipe ends to remove burrs and restore full inside diameter. Join pipe fittings and valves as follows:

1. Note the internal length of threads in fittings or valve ends, and proximity of internal seat or wall, to determine how far pipe should be threaded into joint.
2. Apply appropriate tape or thread compound to external pipe threads (except where dryseal threading is specified).
3. Align threads at point of assembly.
4. Tighten joint with wrench and backup wrench as required.
5. Damaged threads: Do not use pipe or pipe fittings having threads that are corroded or damaged.
6. Sealed with sealant compounds or teflon tape. Hard setting pipe thread cement or caulking shall not be allowed.
7. Sealant compounds: John Crane or Rector Seal:
 - a. General service: John Crane JC-40
 - b. Refrigerant: John Crane No. 2 Plastic Lead Seal
 - c. Chemicals and corrosive service piping: John Crane JC-30

- F. Flanged Joints: Align flange surfaces parallel. Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets as flat and parallel as possible. When required, use suitable lubricants on bolt threads. Tighten bolts gradually and uniformly using a torque wrench.
- G. Mechanical Joints: Grooved copper tube and grooved-tube fitting joints shall be assembled with coupling, gasket, lubricant, and bolts per coupling and fitting manufacturer's standard written procedure. Grooved ends on copper and copper alloy tube shall be roll-formed only using the appropriate roll-groove tool to construct a groove meeting the coupling and fitting manufacturer's written specifications. Cut grooving methods shall not be used on copper and copper alloy tube.
- H. Flared tube Joints: Flared copper tube joints shall be made by the appropriate use of cast copper alloy fittings conforming to ASME B16.26. Flared ends of copper tube shall be of the 45-degree flare type and shall only be made with a flaring tool designed specifically for that purpose. Copper alloy tube shall be reamed to remove burrs and restore full inside diameter prior to forming the flared end.
- I. Welded Joints:
1. Where required, peen and wheel-grind welds.
 2. Ends of pipe may be burned for welding:
 - a. Grind, bevel and remove scale between welding joint.
 - b. Ragged edges with metal beads, poor alignment or other inferior work shall be rejected.
 - c. Preparation of pipe ends: For wall thickness up to 3/16-inch, ends shall be finished square or with 37.5-degree bevel with a 1/16 inch band; for wall thickness 3/16-inch to 3/4-inch inclusive, ends shall be machined or ground to have a 37.5-degree bevel with a 1/16-inch band per latest edition of ASTM B31.1.
 3. Perform welding with oxyacetylene or electric arc process.
 4. Welding shall be from outside only on pipe configurations.
 5. Tack welds shall be of same quality as required in the completed weld and shall be visually examined for defects before applying any complete passes. The ends (starts and stops) of the tacks shall blend in smoothly with the base metal so that subsequent passes can be applied without interruption.
 6. Inspection: Visual inspection shall be done by the welder after each pass.
 7. Inspection Criteria: Cracks, cold laps, open porosity and tungsten inclusions shall not be allowed. If the above occurs, the weldment shall be removed and rewelded per this specification. Weld beads shall be applied in such a manner that they are smooth into adjacent beads and the base metal with no areas, such as crevices, undercuts, or overlaps, that would weaken the structure or prevent adequate penetration of subsequent weld passes. Undercut of the final pass, which reduces the initial material thickness, shall be repaired by additional welding.
 8. Repair: All materials welded using this procedure or which fall within the requirements of this procedure may also be repair welded using this procedure.
- J. Grooved End Joints:
1. Pipe Preparation: The pipe ends must be clean from indentations, projections and roll marks in the area from pipe end to groove for proper gasket sealing. The dimensions must be according to the standard roll groove specifications as recommended by the manufacturer. Cut grooves are not acceptable.
 2. Pipe Preparation Plain End: Black pipe must be thoroughly cleaned down to bare metal for one-inch from the pipe end to receive mechanically coupled fittings; removed pipe coatings, mill scale, rust and raised weld beads.

3. Tighten all nuts to assure firm metal contact of the coupling pads.
 4. Groove width depth and outside diameter must conform to the standard groove specifications in the latest "Field Assembly and Installation Instruction Pocket Handbook".
 5. Before assembly of couplings, lightly coat pipe ends and outside of gasket with cup grease or graphite paste to facilitate installation.
 6. Support branch pipes independently to eliminate stress on coupled joint.
 7. Determine that gasket material and lubricant are compatible with service of pipe.
- K. Soldered and Brazed Joints: Construct soldered joints per ASTM B 828. Construct brazed joints per ANSI/AWS C3.4.
1. Install solder-joint to male-thread adapters, or solder-joint to male-thread unions meeting the requirements of ASME B16.18 or ASME B16.22, adjacent to each threaded valve and threaded equipment connection in a copper tube system.
 2. Install ASME B16.24 cast copper alloy pipe flanges adjacent to each flanged valve and flanged equipment connection in a copper tube system.
 3. Provide brazing for refrigerant piping system using AWS A5.8, BAg1 with 15 percent silver, 80 percent copper and 5 percent phosphorous.
 4. Provide solder joint for building heating hot water supply and return systems, chilled water systems, and condenser water piping.
 5. Clean surfaces to be jointed of oil, grease, rusts and oxides.
 - a. Remove grease from fittings by washing in solution of 1/16 sodium carbonate and three gallons hot water (except as otherwise specified for refrigerant piping).
 - b. Clean socket of fitting and end of pipe thoroughly with emery cloth to remove rust and oxides. After cleaning and before assembly or heating, apply Handy or Aircosil flux to joint surface and spread evenly.
 6. Any joints showing evidence of overheating, cracking, poor penetration, or other defects of fit-up or workmanship shall be replaced as directed by the Architect at the Contractor's expense.
- L. Plastic Piping, General:
1. Threaded joints only at terminal connections or when specifically approved
 2. Threaded joints only on Schedule 80 pipe or with socket-threaded adapters
 3. Teflon joint thread tape
 4. Approved adapters for connections to metallic piping
 5. Heat-Fusion Joints: Make polyolefin pressure-piping joints according to ASTM D 2657.
 6. Plastic-Piping Electrofusion Joints: Make polyolefin drainage-piping joints according to ASTM F 1290.
 7. Fiberglass Piping Joints: Make joints with piping manufacturer's bonded adhesive.
 8. Dissimilar-Material Piping Joints: Make joints using adapters compatible with both system materials.

3.05 CHEMICAL CLEANING

- A. General:
1. During construction:
 - a. Keep openings in piping closed to prevent entrance of foreign matter.
 - b. Clean pipe, fittings and valves internally.
 - c. Hammer welds to remove slag and weld beads.
 2. After completion of pressure testing, chemically clean internally each heating or

3. cooling piping system.
Proceed with chemical cleanout within 4 hours of completion of pressure testing.

B. Water Systems:

1. Upon start-up flush and then fill with clean water, and vent as required.
2. Install temporary filter bags in hydronic system strainers at all pumps or cooling towers during start-up. Replace as often as necessary until they are relatively clean after 48 hours of service from last change.

C. Add chemical cleaning compound: Supplied and supervised by water treatment company. Refer to Section 23 25 00- Water Treatment.

1. Temporary equipment for condenser water system:
 - a. Remove from condenser water piping system and replace after cleaning:
 - (1) Straightening vanes
 - (2) Metering orifices
 - b. Temporary flat screen type strainer:
 - (1) Place in each cooling tower cell inlet during cleaning period.
 - (2) Remove after cleaning period.
2. Circulate water of each system at respective design flow rates.
 - a. Three (3) 8-hour days.
 - b. At end of each 8-hour period remove and clean strainers and blow off low points.
 - c. After third day of pumping, completely drain out entire systems of cleaning solution.
 - d. Clean out cooling tower basins and hose down.
 - e. Refill systems immediately (within 2 hours) with clean water and circulate for additional 8 hour period at end of which interval, completely drain systems.
 - f. Immediately (within 2 hours) refill with clear water; circulate, vent air and add chemical treatment.
 - g. Test for alkalinity: Not more than 200 ppm in excess of alkalinity of water supply.
 - h. Repeat circulation of water of each system at respective minimum design flow rate as described above, until 200 ppm or less, maintained for 10 days.
3. Protect against damage from freeze-up or discharge of water.
4. Provide by-pass valves for all risers to by-pass fan coil units, space terminal heating units, hydronic coils and between supply and return risers to avoid flushing water coils or control valves.

D. Steam and Condensate Systems:

1. Same as for water systems.
2. Prior to cleaning remove traps and provide temporary spool piece.
3. Blow down system with steam after water cleaning and before traps are reinstalled.

3.06 FIELD QUALITY CONTROL

A. General:

1. Any deviation from the cleaning, installation, testing, and certification requirements

- herein shall be approved in writing by the Architect.
2. All materials and workmanship shall be subject to inspection and examination by the Architect at any place where fabrication or erection occurs.
 3. The Architect reserves the right to reject all or any part of the system that does not conform to the requirements herein. Rejected materials or equipment shall be returned at the Contractor's expense for re-cleaning and certification.
 4. The Architect reserves the right to remove random samples of the installed work sufficient to establish the quality of materials and workmanship. If such samples indicate materials and workmanship do not meet the contract specification, the Contractor shall be required to replace or re-clean the installed work at no expense to the Owner. The Owner shall reimburse the Contractor on a time and materials basis for such work if the system proves to be installed to specification.
 5. All testing shall be done in the presence of the Owner representative.
 6. Upon completion of this work, all systems shall be adjusted for use. Should any piece of apparatus or any material or work fail in any of the required pressure tests, it shall be immediately removed and replaced by new materials. The defective portion of the work shall be replaced by the Contractor in the presence of the Owner at no expense to the Owner.
 7. Test gauges shall be installed and test medium source connections shall be made to convenient process connections. After completion of testing, the gauges and source connection shall be removed and the specified process attachments replaced.
 8. Any leaks found shall be repaired in the following manner:
 - a. Welded joint – Grind out defect and re-weld.
 - b. Brazed joint – Cut out and re-braze.
 - c. Plastic joint – Remove/re-weld.
 - d. Screw joint – Taken apart and re-do (do not use compound).

B. Test Preparation:

1. Clean new piping internally by flushing prior to the application of pressure tests, and before the chemical cleanout procedures specified. Provide temporary strainers at the inlet to the hot water, glycol, chilled water, and condenser water pumps before the start of cleaning procedures.
2. Block off and isolate circulating pumps, condensers and hydronic coils and heating coils during the preliminary flushing and draining process.
3. Thoroughly flush piping with water under pressure, clear of foreign matter, and then drain before proceeding with pressure testing. Blow down accumulations of grit, dirt and sediment at each strainer and each low point in the piping systems.
4. Leaks and Defects:
 - a. Repair or replace as directed.
 - b. Repair damage caused by test failure without additional cost.
 - c. Retest repaired and/or damaged systems until tests are accomplished successfully.
5. Refer to other sections for tests to plumbing systems and other special piping systems.
6. Notify Architect in writing one week before test.
7. Maintain a log book of all pressure tests showing dates, personnel performing test, test observer and test results.
8. Furnish written report and certification that tests have been satisfactorily completed.

C. Pressure Tests:

1. Less than 100 pounds per square inch operating pressure: Test hydrostatically to 150 pounds per square inch.
2. Over 100 psi operating pressure:

- a. Test hydrostatically to 1½ times operating pressure.
 - b. Never exceed test pressure ANSI B16.1 basis.
3. With system valves capped and pressure apparatus disconnected, a 4 hour duration pressure test shall exhibit:
- a. No pressure change (zero).
 - b. Maximum allowable pressure change: Shall be 5 percent of test pressure.
 - c. Compensate for temperature change.
4. Steam and hot water heating piping shall be heat stressed by raising temperature to operating level from ambient two times before pressure test.
5. For air tests, gradually increase the pressure to not more than one half of the test pressure; then increase the pressure in steps of approximately one-tenth of the test pressure until the required test pressure is reached. Examine all joints and connections with a soap bubble solution or equivalent method. The piping system exclusive of possible localized instances at pump or valve packing shall show no evidence of leaking.
6. Heat Tracing: After initial installation, and before and after installing the thermal insulation, subject heat tracing to testing using a 2500 volt DC megaohm meter (megger). Minimum insulation resistance shall be between 20 to 1000 megaohms regardless of length. Consult manufacturer if conditions test outside this range; if necessary, new heat tracing and insulation shall be installed to meet test criteria, at no cost to Owner.
7. Leak test refrigerant piping systems by charging to a pressure of 10 psig with an HFC refrigerant, with the compressor suction and discharge valves closed and with all other system valves open. Increase pressure to 300 psig with dry nitrogen. Rap all joints with a mallet and check for leaks with an electric leak detector having a certified sensitivity of at least one ounce per year. Seal any leaks that may be found and retest.
8. Testing Certification: Certify that specified tests, inspections, and procedures have been performed and certify report results. Include the following:
- a. Inspections performed
 - b. Procedures, materials, and gases used
 - c. Test methods used
 - d. Results of tests

END OF SECTION

SECTION 23 21 23

PUMPS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Split case pumps
 - 2. End suction base mounted pumps
 - 3. In-line circulating pumps
 - 4. Vertical in-line pumps
 - 5. Cooling coil condensate pumps
 - 6. Manufacturer's factory representative's supervision of installation and start-up

1.02 QUALITY ASSURANCE

- A. Alternates to scheduled pumps shall operate at or near their point of peak efficiency, allowing for operation at capacities of approximately 25 percent beyond design capacity. Maximum impeller size shall not exceed 85 percent of the difference between the maximum and minimum impeller diameter.
- B. In order to insure stable operation and prevent any possibility of hunting, the pump curve shall be continuously rising from maximum capacity up to the shutoff point. Pumps shall be non-overloading over the full range of the pump curve.
- C. Furnish each pump and motor with a metal engraved nameplate giving the manufacturer's name, serial number of pump, capacity in GPM and head in feet at design condition, horsepower, voltage, frequency, speed and full load current.
- D. All pumps shall operate without excessive noise or vibration.
- E. Furnish one spare seal and casing gasket for each pump to Owner.

1.03 SUBMITTALS

- A. Shop drawing submittals shall include pump curves, net positive suction head requirements, and pump performance characteristics with pump and system operating points plotted.
- B. Submit construction details, materials of construction, type of seals, pump base, and mounting details.
- C. Submit motor construction, winding type and efficiencies as specified in Section 23 05 13 - Electric Motors.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Split Case: Paco, Peerless, Aurora, B&G.
- B. End Suction: Armstrong, Paco, B&G, Aurora, Taco.
- C. In-Line Circulators: Armstrong, Paco, B&G, Aurora, Grundfos, Taco.

- D. Vertical In-Line: Armstrong 4300 Series, B&G Series, Paco VL Series, Taco KS Series.
- E. Cooling Coil Condensate: Little Giant VCMA-20 Series., March, Beckett CB, Hartell KTP20.

2.02 SPLIT CASE PUMPS

- A. Provide mechanically sealed split case pumps with John Crane Type 1B, elastomer, non-pusher type balanced mechanical seals on pump serving system above 150 pounds per square inch gauge. Provide unbalanced mechanical seals on pumps serving system with 150 pounds per square inch gauge rating.
- B. Pump bearings shall be heavy-duty conrad type suitable for grease lubrication and contained in moisture and dust-proof bearing housings with a minimum B₁₀ life of 20,000 hours.
- C. Provide flanged connections on suction and discharge sizes 2½ inches and larger, drilled to ANSI standards complete with pressure gauge taps.
- D. Pumps shall be of the single-stage horizontal split case type. Suction and discharge connections shall be located on opposite sides of the lower half casing, allowing removal of the rotating element without disturbing the system piping connections. Pump speed shall not exceed 1750 revolutions per minute unless scheduled otherwise. The maximum brake horsepower requirements of the pump shall not enter the service factor rating of the motor.
- E. A steel drip rim base shall be furnished for each pump unit. Pump and drive unit shall be carefully aligned and bolted in place prior to factory shipment.
- F. The casing shall be close-grained cast iron free from blowholes, sand pockets and other detrimental defects. Liquid passageways shall be smooth and contoured to permit maximum efficiency. Casting shall be designed for working pressure as scheduled and shall be hydrostatically tested at 150 percent of the maximum working pressure. Suction and discharge flanges shall be drilled to ANSI standards.
- G. The impeller shall be of the double suction type, made of cast bronze, and balanced statically, hydraulically and dynamically. The impeller shall be keyed to the shaft, securely retained in an axial position by positive mechanical means with all sharp or rough edges beveled smooth.
- H. The pump case shall have two bronze case wear rings, one located at each impeller skirt. Each ring shall be pinned to lock the ring in place.
- I. A factory aligned EPDM flexible coupling suitable for variable speed drive operation shall be provided. Each pump mounted with a motor shall be equipped and shipped from the manufacturer with an OSHA approved coupling guard in place.

2.03 END SUCTION BASE MOUNTED PUMPS

- A. Pump shall be of the end suction, vertically split case centrifugal type.
- B. The casing shall be close-grained case iron free from blowholes, sand pockets and other detrimental defects. Liquid passageways shall be smooth and contoured to permit maximum efficiency. Casing shall be designed for working pressure as scheduled and shall be hydrostatically tested at 150 percent of the maximum working pressure. Suction and discharge flanges shall be drilled to ANSI standards.
- C. A steel drip rim base shall be furnished for each pump unit. Pump and drive unit shall be carefully aligned and bolted in place prior to factory shipment.
- D. The impeller supplied for the specified conditions shall be a one-piece bronze casting and

balanced statically, hydraulically and dynamically. The impeller shall be keyed to the shaft and securely retained in an axial position by positive mechanical means.

- E. Pump shaft shall be carbon steel with stainless steel or bronze shaft sleeve, sized, and designed to limit shaft deflection at the seal to no more than 0.002 inches.
- F. Provide mechanically sealed suction pumps with John Crane Type 1B, elastomer, non-pusher type balanced mechanical seals on pump serving system above 150 pounds per square inch gauge. Provide unbalanced mechanical seals on pumps serving system with 150 pounds per square inch gauge rating.
- G. Pump bearings shall be heavy-duty conrad type suitable for grease lubrication and contained in moisture and dust-proof bearing housings with a minimum B₁₀ life of 20,000 hours.
- H. Provide flanged connections on suction and discharge sizes 2½ inches and larger, drilled to ANSI standards complete with pressure gauge taps.
- I. Provide pumps suitable for maximum system working pressure with pump seals rated to operate continuously at fluid temperature up to 250 degrees F.
- J. Provide bronze replaceable case wear ring. Ring shall be pinned to lock the ring in place.
- K. Pump shall have EPDM flexible coupling suitable for variable speed drive operation. Motor and pump shall be factory aligned and mounted on a steel or cast iron drip rim base. An OSHA approved coupling guard shall be provided.

2.04 VERTICAL IN-LINE PUMPS

- A. Pump shall be of the vertical in-line bronze fitted, single stage centrifugal type, split-coupled to a vertical electric motor.
- B. The casing shall be close-grained cast iron free from blowholes, sand pockets and other detrimental defects. Liquid passageways shall be smooth and contoured to permit maximum efficiency. Casing shall be designed for working pressure as scheduled and shall be hydrostatically tested at 150 percent of the maximum working pressure. Suction and discharge flanges shall be drilled to ANSI standards.
- C. Suction and discharge connections shall be the same size, flanged, 180 degrees opposite on centerline for pipeline mounting.
- D. Casing shall have bronze replaceable wear ring.
- E. Impeller shall be a one-piece bronze casting, enclosed, statically, dynamically, and hydraulically balanced.
- F. Motor shaft shall be solid carbon steel with bronze or stainless sleeve.
- G. Provide John Crane Type 1B, elastomer, non-pusher type balanced mechanical seals on pump serving system above 150 pounds per square inch gauge. Provide unbalanced mechanical seals on pumps serving systems with 150 pounds per square inch gauge rating. Seals shall be removable without disassembly of piping or motor.
- H. Pump bearings shall be heavy-duty conrad type suitable for grease lubrication and contained in moisture and dust-proof bearing housings with a minimum B₁₀ life of 20,000 hours.
- I. Provide pumps suitable for maximum system working pressure with pump seals rated to operate continuously at fluid temperature up to 250 degrees F.

2.05 IN-LINE CIRCULATORS

- A. In-line circulating pumps shall be direct-coupled bronze or stainless steel fitted with a dynamically balanced brass or stainless steel enclosure type impeller and with mechanical seal. Mechanical seal shall be Type 1B as manufactured by John Crane Company. Motor shall have a maximum speed of 1750 rpm.
- B. Suction and discharge connections shall be the same size, flanged, 180 degrees opposite on centerline for pipeline mounting.
- C. Provide pumps suitable for maximum system working pressure with pump seals rated to operate continuously at fluid temperature up to 250 degrees F.
- D. Multi-stage inline pumps
 - 1. The pump end shall be of the horizontal multi-stage design. The pump shall be furnished as shown on the plans and installed in accordance with the recommendations of the manufacturer.
 - 2. The pump shall be capable of continuous operation at fluid temperatures between 32 and 104 degrees F up to 145 psi operating pressure, or to 194 degrees F up to 87 psi operating pressure.
 - 3. The suction and discharge chamber and motor stool shall be constructed of cast iron. The impellers, diffuser chambers and impeller seal retainers shall be constructed of AISI 304 stainless steel.
 - 4. The pump shaft shall be AISI 431 stainless steel and be part of the rotor assembly, requiring no coupling or adjustment. The impellers shall be secured directly to the pump shaft by means of a splined shaft arrangement.
 - 5. The pump shall be equipped with Tungsten Carbide rotating and stationary seal faces or ceramic rotating and carbon stationary seal faces, with EPDM or FKM rubber parts mounted in stainless steel seal components.
 - 6. The motor shall be of the horsepower, voltage, phase and frequency as shown on the drawings. Motor design shall be of the extended shaft design, matched to the number of chambers and shall be Totally Enclosed Fan Cooled (IP44), Insulation Class F. The motor bearings shall be sized to ensure long motor life.
 - 7. The pump and motor shall be U.L. listed. Grundfos model CH or approved equal.

2.06 COOLING COIL CONDENSATE PUMPS

- A. Provide a fully automatic condensate removal pump with 1/2-gallon capacity integral leakproof tank. Pump capacity shall be 20 gallons per hour with a 15-foot lift.
- B. The pump shall be a vertical-type with stainless steel motor shaft, rust proof, high-impact ABS tank and motor cover, 3 drain inlet connections.
- C. Provide a removable 3/8-inch barbed check valve.
- D. Provide a safety switch and relay rated at 5 amperes/48 volts to shut down the associated HVAC unit or wired to a tank high level alarm.
- E. Pump shall be rated for high-efficiency gas furnace applications that produce an acidic condensate.
- F. The 120-volt single phase motor shall be thermally protected motor and UL-listed for hardwire connection.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. The mechanical contractor shall be responsible for aligning in the field prior to startup of all flexibly coupled pumps. Alignment accuracy of plus or minus 0.002 inch shall be verified with a dial indicator. Prior to start-up, the manufacturer shall submit a written report certifying that the alignment work has been performed and that the pumps are ready for operation.
- B. Base mounted pumps shall be leveled up on tapered steel wedges in such manner to permit a minimum of ¾ inch of grout between the pump base and the top of the concrete base.
- C. Pump motor, suction and discharge openings shall be covered during construction period. If the motor is started, the Contractor shall be responsible to ensure that the environment in which the motor is running is clean.
- D. Install condensate pumps with tank level and allow access for tank removal.

3.02 PIPING

- A. Install all pumps in strict accordance with manufacturer's instructions. Access/service space around pumps shall not be less than minimum space recommended by pump manufacturer.
- B. Support piping adjacent to pump such that weight is not carried on pump casings.
- C. Decrease from line size at pump connections with long radius reducing elbows or concentric reducers/increasers in the vertical piping, or eccentric reducers/increasers for horizontal piping. Install eccentric reducers/increasers with the top of the pipe level
- D. At all pump suctions, install a straight pipe length of 4 times the suction diameter.
- E. Seals for all pumps serving condenser water or open cooling towers shall be supplied with a flushing water line piped with Crane Kynar Series 100 abrasive separator and Akron ball type sight flow indicator.
- F. Provide needle valves and drain connection on pump casings, or at pump inlets to allow for complete drainage of pump casing.
- G. Connect pump discharge to copper condensate drain piping with a 8-inch long maximum length of clear plastic tubing.

END OF SECTION

SECTION 23 22 33
STEAM SPECIALTIES

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. Steam condensate traps
- B. Steam relief valves
- C. Steam flash tanks and flash legs
- D. Steam condensate pumping units

1.02 SUBMITTALS

- A. Shop drawings: Submit steam pressure reducing valve rig construction details and performance data, steam traps (including basis of selection of each), relief valves, and steam separators, including all sizing, construction, performance and capacity information.
- B. Submit details of flash tank assemblies and fabrication of pipe anchors, hangers, special pipe support assemblies, alignment guides, and expansion joints and loops and their attachment to the building structure. Include dimensions, weights, loadings, required clearances, method of field assembly, components, and location and size of each field connection.
- C. Submit product data: For each type of special-duty valve and steam trap indicated, including rated capacities and accessories. Manufacturer's latest published data for materials, equipment and installation.

1.03 QUALITY ASSURANCE

- A. Comply with all requirements of ANSI/ASME B31.1.
- B. Traps shall be rated in accordance with Steam Heating Manufacturers Association Code.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Steam Condensate Traps: Armstrong, Hoffman, Spirax Sarco
- B. Safety and Relief Valves:
 - 1. Up to 150 psig, 2-inch: Kunkle Series 6000, Consolidated 1541, Lonergan Model A Series, Sarco Series 6010
 - 2. Up to 150 psig, 2½-inch and larger: Kunkle Model 252, Consolidated 1511, Lonergan Y Series, Sarco SVI
- C. Air Vents and Vacuum Breakers: Armstrong, Barnes & Jones, ITT Hoffman, Johnson Corp, Spirax Sarco

2.02 STEAM CONDENSATE TRAPS

- A. Thermostatic Trap:

1. Construct trap of cast iron body with suitable outlets and cap, large renewable brass or nickel port and a valve operated by a metallic bellows or multiple diaphragm in which a volatile fluid is sealed.
- B. Combination Float and Thermostatic Trap:
1. Construct trap of cast iron body or semi-steel body and bolted cover with non-asbestos cover gasket. Provide suitable side inlet-side outlets, cap and a large renewable brass or nickel port. Valve shall be operated by a multiple diaphragm in which a volatile fluid is sealed, or a stainless steel bellows type air vent, stainless steel float, stainless steel lever and valve assembly. Trap shall be rated at [125] [15] psig saturated steam.
 2. Thermostatic air vent capable of withstanding 45 degrees F of superheat and resisting water hammer without sustaining damage. Construct of [stainless steel] [bronze].
- C. Inverted Bucket Trap:
1. Cast iron or semi-steel body and bolted cover, non-asbestos cover gasket, stainless steel bucket, stainless steel or heat treated chrome steel seat and plunger, integral inlet strainer with stainless steel screen and tapped and plugged blowdown connection, rated at not less than 150 psig saturated steam. Sealed stainless steel traps may be substituted for cast iron traps if the pressure/temperature and other construction limitations are met.
 2. Forged carbon steel body with bolted cover, non-asbestos cover gasket, stainless steel bucket, stainless steel or heat-treated chrome steel seat and plunger, rated at not less than 175 psig steam at 430 degrees F.
- D. Thermodynamic Trap:
1. Construct entirely of stainless steel with teflon seal ring and gasket, maximum operating pressure of 600 psig.
 2. Provide a stainless steel screw-in cap over disc cap to further insulate and protect disc.

2.03 SAFETY AND RELIEF VALVES

- A. General:
1. Provide relief valves for heat exchangers, flash tanks, boilers, deaerators and pressure reducing stations, as shown in the Drawings or as required by code.
 2. Provide safety and relief valves ASME stamped and certified by National Board of boiler and pressure vessel inspectors and rated for the intended service.
 3. Provide valve connections flanged for 2½-inch inlet connections and larger; and screwed for 2-inch inlet connections and smaller, unless equipment nozzles have flanged connections.
- B. Relief Valve Capacity:
1. Provide relief valves for flash tanks capable of relieving flash vapor at 20 lbs. per square inch relief pressure, or as noted on Drawing.
 2. Provide relief valves for heat exchangers to relieve the full heat generating capacity as shown on the Drawings at 7 lbs. per square inch relief pressure.
 3. Provide required safety relief valves to carry 100 percent of each largest scheduled service capacity in each step of pressure reducing stations.

2.04 VACUUM BREAKERS AND THERMOSTATIC AIR VENTS

- A. Quick Vents: Cast-iron or brass body, with balanced-pressure, stainless steel or monel

thermostatic bellows and stainless-steel heads and seats.

- B. Float Vents: Cast-iron or brass body, seamless brass float, balanced-pressure thermostatic bellows, and replaceable stainless-steel seat, float, and head.
- C. Vacuum Breakers: 150 psig steam working pressure, 365 degrees F maximum operating temperature, brass or stainless-steel body, and stainless-steel retainer, spring, and ball; with plain or threaded outlet.

PART 3 – EXECUTION

3.01 STEAM CONDENSATE TRAPS

A. Installation:

1. Provide a thermostatic trap at the return end of each steam convactor.
2. Provide a combination float and thermostatic trap at the return end of each unit heater, steam coil section, heat exchanger, domestic hot water heater, drip points in low pressure steam mains, drip points in boiler supply headers, and elsewhere as specified, indicated, required or directed.
3. Provide traps with unions, inlet strainer, check valve and hand valves as shown on the Drawing. Provide parallel traps with isolation valves for coils subject to freezing.
4. Provide thermodynamic traps for dripping high and medium pressure steam mains and equipment (except boiler supply header).
5. Provide condensate return traps required throughout the steam-condensate system for automatically trapping condensate and expelling air from steam-using elements, as well as from riser end pockets and ends of steam mains and branches.
6. For every trap, provide a complete drip trap rig as specified or detailed on the Drawings. Minimum requirements are as follows:
 - a. Install a valved test tee on the discharge of all traps, as detailed.
 - b. Install a strainer upstream of all drip traps and all terminal equipment where a strainer is not present upstream of the control valve at the terminal.
 - c. Install a shutoff valve upstream of each drip trap; shutoff valves are not required when the trap is at a piece of equipment, which has a shutoff valve in the steam line serving it.
 - d. Install a line size dirt leg at each trap.
7. Trap elevation to be not less than one foot below the equipment outlet connection. Provide a separate trap for each equipment outlet connection
8. Automatically drain condensate free of noise and water hammer. Make all necessary changes to the piping and arrangement of equipment to free the system of objectionable noise and water hammer. For modulating service, use integral vacuum breaker in steam trap.
9. Install the entire system of return line piping so that condensate will be returned by gravity to the condensate pumps and/or condensate cooler without water hammer. Direct the manufacturer of specialties to supervise their attachment and make all adjustments necessary for their operation.
10. Install a steam shutoff valve at the blowdown connection of each trap containing a strainer; terminate the blowdown connection with a nipple and an end cap.
11. Do not lift condensate from the discharge of any trap without the written permission of the Architect.

B. Capacities:

1. Determine trap capacity by multiplying the design condensing rate by the following factors:

- a. Radiation and unit heaters multiplied by 1.5.
 - b. Heat exchangers, hot water tanks, unit ventilators multiplied by 2.0.
 - c. Heating coils multiplied by 2.5.
 - d. Preheat and 100 percent outside air coils multiplied by 3.0.
2. Select traps for modulating duty (control) to accommodate the more stringent of:
 - a. The above capacities at full pressure (control valve wide open).
 - b. Design capacity at $[\frac{1}{2}]$ $[\frac{1}{4}]$ pounds per square inch gauge.
 3. Size traps for dripping boiler supply headers to accommodate 10 percent of design flow at line pressure.
 4. Size traps for dripping mains for the more stringent of:
 - a. Calculated warm-up condensing requirements at line pressure.
 - b. Two times calculated flowing condensate requirements at line pressure.
 5. Select and size traps in accordance with manufacturer's published recommendations when more stringent than above criteria.

3.02 RELIEF VALVES

- A. Provide relief piping equal to or larger than the outlet size of the relief valve. Where two relief valves are joined, continue the larger pipe size to the point of relief.
- B. Use air pressure to clean piping prior to installation of safety relief valves.
- C. Install relief valves in locations indicated on drawings, downstream of all pressure reducing valves, and on all boilers.
- D. Install valves in the vertical position, with drain holes, including those from dip pan elbows, piped to the nearest drain.
- E. Inlet and outlet piping connecting to valves must be the same size as valve connections or larger.
- F. Vent steam safety valves to a location outside of building, in the most direct manner possible. Install drip pan elbow as detailed at first vertical rise of the vent pipe. Keep pipe between safety valve and drip pan elbow as short and straight as possible.
- G. Support piping and drip pan elbow independently to prevent stress at connections to safety valves. Install vent pipe so that its weight does not rest on the drip pan elbow. Extend drain line from drip pan elbow and relief valve to nearest drain.
- H. Pipe discharge from water system relief valves to nearest drain.

3.03 ACCESSORIES

- A. Install vacuum breakers on steam heating coils, steam-to-water heat exchangers, and elsewhere as specified or indicated on the drawings. Where vacuum breakers are not furnished integral with equipment by the equipment manufacturer, provide 15-degree swing check valve.
- B. Provide coil siphons in gauge piping for all gauges used on steam services.
- C. Provide flash legs constructed of schedule 80 steel pipe with 7/8-inch steel plates welded to the pipe top and bottom. Refer to Drawings for tappings connection arrangement, sizing and auxiliary devices.

- D. Provide flash tanks constructed of welded black iron sheet not less than 3/16 inch thick with reinforced threaded tappings for condensate return, vent and condensate discharge. Hang tanks from building structure in a manner approved by the Architect. The tanks shall be fitted with gauge glass and shutoff cocks, of sufficient length to determine level of condensate in the tanks. Provide one coat of high temperature oxide paint on exterior surfaces. Unless otherwise noted on the Drawings, all flash tanks shall be 30 inches in diameter and 36 inches long.

END OF SECTION

SECTION 23 25 00

WATER TREATMENT

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this section shall include, but is not limited to, the following:

1. Heating hot water ~~[glycol]~~ piping
2. Chilled water ~~[glycol]~~ piping
3. Open condenser water piping and in closed circuit cooling towers
4. Closed condenser water piping
5. Steam and condensate return piping
6. Steam boilers
- ~~7. Heat recovery piping~~
- ~~8. Evaporative condenser~~
7. Chemical treatment equipment, chemicals and service
- ~~10. Glycol~~

1.02 SUBMITTALS

A. Submit the following for review:

1. Makeup water analysis
2. Layouts of feeding equipment
3. Details of testing equipment
4. Description of treatment program including calculations, list of chemicals and quantities of chemicals to be used on a daily, weekly and monthly basis.
5. Provide system schematics showing the following:
 - a. Condenser Water System:
 - (1) Circulation rates
 - (2) Pressures
 - (3) Temperature differential across cooling tower and condenser
 - b. Chilled Water, Closed Condensing Water and Hot Water Systems:
 - (1) Volume
 - (2) Circulation rates
 - (3) Pressures
 - (4) Temperature differentials
 - c. Steam Systems:
 - (1) Steam rate
 - (2) Pressure
 - ~~(3) Condensate return rate~~
6. Provide written report witnessed by Contractor containing log and procedure of system cleaning, giving times, dates problems encountered and condition of water.
7. Manufacturer's installation instructions.
8. Manufacturer's descriptive literature, operating instructions, and maintenance and repair data.
9. Properties and product datasheets for all chemicals and glycols.

1.03 REFERENCE STANDARDS

- A. Published specifications standards, tests or recommended methods of trade, industry or governmental organizations apply to work in this section where cited below:
1. NEMA National Electrical Manufacturing Association
 2. ASHRAE American Society of Heating Refrigeration and Air Conditioning Engineers
 3. UL Underwriters Laboratories
 4. OSHA Occupational Safety and Health Act
 5. EPA Environmental Protection Agency
 6. UBC Uniform Building Code
 7. UMC Uniform Mechanical Code
 8. UPC Uniform Plumbing Code
 9. The State of Washington Codes
 10. Local Codes

1.04 QUALITY ASSURANCE

- A. Retain a national water treatment chemical company to provide water treatment chemical feed equipment and chemicals for circulating water systems, steam systems and equipment as defined herein and as may be required to maintain the integrity of the piping systems and mechanical equipment.
- B. The water treatment chemical and service supplier shall be a recognized specialist, active in the field of industrial water treatment, whose business is in the field of water treatment, and who has full time personnel within the trading area of the job site. Supplier shall have completed five existing chemical treatment systems of equal or greater in size as this project and these projects shall have been operating for a minimum of two years.
- C. Furnish and install all equipment and material on this project in accordance with the requirements of the authority having jurisdiction, suitable for its intended use on this project, approved by the Environmental Protection Agency (EPA), and so certified by the manufacturer.
- D. Analyze water from the local water company to be used on the project before establishing treatment procedures.
- E. Treatment Standards Control levels are listed in ppm (parts per million) or as noted:
1. Open Condenser Water Systems:
 - a. Non-toxic organic corrosion and scale inhibitor. Control Level - 300 ppm as total organic inhibitor.
 - b. Molybdate Residuals. Control Level - 5-10 ppm.
 - c. Organic Flocculating Agent. Control Level - 1 ppm.
 - d. Organic Growths. Control Level - None. Apply non-oxidizing EPA registered biocide when necessary.
 - e. pH: Control Level - 8-9. Apply acid or alkali if required. To be determined from an analysis of makeup water and local atmospheric conditions.
 - f. Cycles of Concentration. Control Level - 6-8. Actual cycles of concentration to be determined from an analysis of the makeup water.
 2. Closed Recirculating Water Systems: Hot water, glycol, chilled water and closed condenser water (220 degrees F maximum).
 - a. Non-toxic organic corrosion and scale inhibitor. Control Level - 2000 ppm as total organic inhibitor.
 - b. Molybdate. Control Level - 200-300 ppm.

- c. Nitrate. Control Level - 500-700 ppm Hot Water as NO₂, 300-500 ppm Chilled Water as NO₂.
 - d. pH: Control Level - 7-9.
3. Steam:
- a. Non-toxic organic corrosion and scale inhibitor: Control Level - 3000-4000 ppm as total organic inhibitor (depending on feedwater hardness and iron level).
 - b. pH – Boiler Water. Control Level - 11 minimum.
 - c. pH – Steam Condensate. Control Level - 8.2-8.8.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Chemical Water Treatment Service:

- 1. Nalco
- 2. Mogul
- 3. Garret-Callahan

2.02 PRESTART-UP CLEANING AND FLUSHING

- A. Furnish all required pipe cleaning chemicals, chemical feed equipment, materials, and labor necessary to clean the piping as herein specified. In addition, permanently install necessary chemical injection fittings complete with tubing, unions, sampling cocks, stop valves and coupon racks, etc.
- B. Provide a pre-startup, non-foaming, liquid detergent dispersant cleaner for cleaning of all water systems to remove oil and foreign material from the piping and equipment prior to the final filling of the systems. This chemical shall not be injurious to persons, piping, pipe joint compounds, packing, coils, valves, pumps and their mechanical seals, tubes, gaskets or other parts of the system.
- C. Furnish instructions dictating the quantities of the cleaner to use, methods and duration of the operation. Refer to Section 23 21 13 for cleaning procedure.

2.03 WATER TREATMENT CHEMICALS

- A. Provide a one-year's supply of necessary water treatment chemicals including the following:
 - 1. Closed System Chemical Treatment (Chilled Water, Closed Condenser Water and Hot Water):
Liquid nitrate to reduce scale deposits, to adjust pH and to inhibit corrosion. Treatment shall not contain any chromates or other toxic substances.
 - 2. Open Condenser Water Chemical Treatment System:
Agent to inhibit scaling, acid or alkali to treat alkalinity and pH, corrosion inhibitor and biocides. Biocides shall be alternated periodically to prevent algae from developing immunity. Materials shall not contain any chromates, mercury, tin, arsenic or any toxic substances. Recommended biocides of an oxidizing and a non-oxidizing composition shall be registered with the U.S. Environmental Protection Agency and EPA registration numbers are to be clearly shown on all product literature and drum labels.
 - 3. Steam System:
Agents shall scavenge oxygen, control hardness and alkalinity and inhibit corrosion. Use neutralizing amines as approved by USDA, USPHS, FDA and OSHA.
 - 4. Open Systems (Humidifier/Dehumidifier):

Agents shall inhibit scaling and corrosion; provide alternating biocides.
Biocide program shall consist of an oxidizing and non-oxidizing treatment.

2.04 WATER TREATMENT CONTROL TESTING EQUIPMENT

- A. Supply one year's quantity of testing chemicals to properly analyze the treated water. Provide separate test kit for each chemical used.
- B. Provide Myron L "DS" meter with a range of 0-5000 micro-ohms per centimeter with automatic temperature compensation from 50 to 160 degrees F with 9-volt transistor batteries.
- C. Furnish a one-year supply of log sheets on which to record the test results and bound copy of full test instructions.

2.05 CHEMICAL FEED EQUIPMENT FOR CLOSED WATER SYSTEMS

- A. Provide bypass pot feeders with 5 gallon capacity, 3/4-inch brass drain valve furnished with slotted lexan inlet and outlet strainers and sight flow indicator and able to withstand the maximum system working pressure. Wingert, Lakewood, Nalco or approved equal.

2.06 BOILER FEED

- A. Provide a packaged treatment unit to automatically feed chemicals to condensate tank or deaerator, consisting of the following:
 - 1. One 50-gallon polyethylene mixing tank with steel stand, level graduations molded into the sides, lift off cover, column for mounting an agitator and low level alarm switch and drain valve.
 - 2. One gear driven 120 rpm agitator with totally enclosed 1/4 horsepower motor with Type 316 stainless steel shaft.
 - 3. One positive displacement pump mounted under the tank, rated at 6 gallons per hour, 250 pounds per square inch, with 1/4 horsepower single-phase motor and controller. Pumps as manufactured by LMI, Neptune, Milton Roy or approved equal.
 - 4. Catalyzed sodium sulfide oxygen scavenger shall be fed by itself into deaerator storage section (below water line). Remaining chemicals may be fed to deaerator drop leg prior to or after feedwater pumps depending on chemical compatibility with pump materials.
 - 5. Piping shall include suction piping, strainer, shutoff valve and pressure relief valve, minimum 1/4-inch and pre-piped with return to tank.

2.07 BOILER WATER TREATMENT

- A. Applicable to steam boilers up to 50 boiler horsepower and 100 pounds per square inch operating pressure.
- B. System equipment, as previously specified:
 - 1. Low pressure chemical metering pump
 - 2. Liquid level switch
 - 3. Automatic blowdown valve assembly
 - 4. Solution tank
 - 5. Agitator
 - 6. Sample cooler
- C. Test kits as previously specified:
 - 1. Ortho phosphate or organic test if using polymer treatment

2. Sulfite
3. Alkalinity
4. Hardness
5. pH
6. Conductivity meter

D. Chemicals:

1. Alkaline boilout compound
2. Alkalinity builder compound
3. Orthophosphate or polymer
4. Sulfite compound
5. Neutralizing amines

2.08 CLOSED SYSTEM WATER TREATMENT

A. Typical for:

1. Closed Condensing Water
2. Heating hot water piping
3. Chilled water piping
4. Heat recovery water
4. Glycol solution piping

B. Provide bypass feeder: five-gallon capacity.

C. Test kits as previously specified: Nitrite.

D. Chemicals:

1. Alkaline boilout compound
2. Nitrite corrosion inhibitor

2.09 OPEN SYSTEMS (Spray Systems)

- A. Provide an automatic drip feeder with coil of capillary tubing with probe, weight, charging syringe and clip to feed treatment chemicals. Provide solenoid valve on drip feed to close when spray pump is off.

PART 3 – EXECUTION

3.01 TECHNICAL SERVICE AND CONTROL

- A. Water treatment equipment shall be located in mechanical equipment rooms or spaces when feasible to do so.
- B. Supervise the installation of water treatment equipment.
- C. Supervise the cleaning of open and closed systems and provide a written certification of cleanliness at completion of cleaning procedure.
- D. Provide a four-hour training program to the Owner's operating personnel instructing them clearly and fully on the installation, care, maintenance, testing, and operation of the water treatment system. The training course shall be arranged by the mechanical contractor at the startup of the system.
- E. For a period of one year after completion of system commissioning, provide the services of a

fully qualified field engineer for one year at no additional cost to the Owner. This field engineer must be a graduate chemist or chemical engineer and shall be active in the water treatment field in this locale. The water treatment company shall also provide laboratory and technical assistance from a fully qualified engineering staff to support the following tasks.

1. Make monthly technical service visits to the installation to perform field inspections and to make water analysis on site, with sufficient complexity as to evaluate the water systems operations. Discuss findings with the Owner's personnel in writing advising on proper practices, chemical requirements and any corrective actions needed to protect the water systems from scale, corrosion, and fouling. Copies of the field service report must be forwarded each month to the Owner, Architect and Engineer.
2. Make on-site inspections of equipment during scheduled or emergency outages in order to properly evaluate the success of the water treatment program and to make recommendations in writing based upon these inspections.

3.02 INSTALLATION

A. Chemical Feeders:

1. Chemical pumps shall be mounted at height suitable for pumping chemical treatment solutions directly from supply drums to condenser water system.
2. Top of reservoir tank maximum 4 feet above floor. Provide drip pan of same material as tank with drain under tank and pumps.

B. Piping:

1. Proportioning pump piping shall include pressure gauge and relief valve on discharge line.
2. Install by-pass feeders:
 - a. Install feeder in location convenient for filling.
3. ~~Condenser~~ Open condenser water systems:
 - a. Bleedoff:
 - (1) Provide approved bleed manifold with:
 - (a) Solenoid bleed valve
 - (b) Manual bypass valve
 - (c) Piping to drain
 - (2) Bleedoff rate controllable.
 - b. Provide accessible City water hose connection at system basins for cleaning and flushing.
 - c. Provide sample stream injection assembly:
 - (1) 316 stainless steel injection pipe
 - (2) All necessary compression connectors
 - (3) Safety retaining ring
 - (4) Threadolet
 - (5) Full port gate valve
4. Drain connections at low points of piping.

C. System connections and feeder locations shall be approved in the field by water treatment

firm before installation of treatment equipment begins.

3.03 INITIAL CLEANING OF SYSTEMS

- A. Prior to operation, clean system as specified.
- B. Upon completion of cleaning, dose system with chemicals to obtain specified treatment conditions.

END OF SECTION

SECTION 23 25 16

WATER FILTER AND CYCLONE SEPARATOR

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this section shall include, but is not limited to the following:

1. Well filter.
2. Well ~~tower~~-water cyclone separator with controls, valves and closed loop liquid recovery tank.

1.02 RELATED DOCUMENTS

- A. Section 23 05 01 - Mechanical General Provisions
- B. Section 23 05 13 - Electric Motors
- C. Section 23 21 23 - Pumps
- D. Section 23 25 00 - Water Treatment
- E. Section 23 65 33 – Fluid Coolers

1.03 SUBMITTALS

- A. Submit manufacturer's catalog data for the pump, motor filter, separator, valves and all appurtenances.
- B. Submit all component sizes, capacities and piping arrangements.
- C. Submit controls, mounting details, materials of construction.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Water Filters: Process Efficiency Products, Filtomat, United Industries.
- B. Cyclone Separators: Lakos, Griswold, Filtrite.

2.02 WATER FILTERS

- A. Provide a pre-engineered, factory assembled industrial water filter system with interconnecting piping to the well water piping as shown on the Drawings. The system shall be complete with filter tank, filtration media, overdrain assembly, underdrain assembly, pressure gauge, circulation pump, pre-strainer, control panel, automatic and hand valves, vibration isolation base, filtration piping and backwash piping.
- B. Filter tank shall be constructed of 16 gauge minimum 304 stainless steel with a top mounted pressure gauge. The internal underdrain assembly shall have removable laterals. Provide positive sealing gasketed access to the internal components of the tank.
- C. Filtration media shall consist of silica sand particles of size and shape to ensure efficient

removal of solids during filtration and quick release of trapped solids during backwash. The media shall remove minimum 98 percent of the suspended particles larger than 15 microns from the circulated water. A minimum of 95 percent of all filtration media particles shall be round grain silica sand of sizes between 20 and 40 U.S. sieve screen size.

- D. Overdrain assembly shall provide a balanced hydraulic flow for optimal water distribution over the media.
- E. Underdrain assembly of PVC shall be designed to prevent sand media passage in the filtration mode and to ensure complete flooding of the media during backwash. Filter shall be supplied with automatic city water backwash controls, piping, valving and wiring.
- F. Provide a circulating water pump of close-coupled centrifugal design, bronze construction, bronze impeller, mechanical seals and basket type inlet strainer. Pump motor shall be TEFC design for outdoor installation and selected below the service factor range at maximum pressure drop corresponding to dirty media. The flow capacity shall be capable of recirculating the entire condenser water system volume at least once per hour during operation.
- G. Provide a factory pre-wired control panel including magnetic starter with thermal overload and circuit breaker protection, fused stepdown transformers, backwash timer, heat tape, electrical power and controls, fuse protection, terminal strip, automatic valve sequencer, cam type clock and pressure switch actuator. Provide two 120-volt electrical relay contacts for use by the Building Management System.
- H. Two three-way, two-position brass ball valves with mechanical linkage and motorized actuators shall switch from filtration to backwash modes.
- I. Provide mounting base of 1½-inch thick ribbed cast iron baseplate.
- J. The control system shall be pre-piped and pre-wired for automatic operation. Backwash shall clean the filter media when the differential pressure across the filter tank reaches an operator adjustable setpoint. Provide an operator adjustable backwash timer.

2.03 CYCLONE SEPARATORS

- ~~A. Provide a pre-engineered, factory assembled centrifugal separator system with interconnecting piping to the well water piping as shown on the Drawings. The system shall be complete with flanged inlet and outlets, pressure gauges, automatic purge system, automatic and hand valves, piping, 1½-inch purge outlet, mounting bracket.~~
- ~~B. Separation tank shall be constructed of 3/16-inch carbon steel with top mounted pressure gauge and auto-purge system. Provide positive sealing gasketed access to the internal components of the tank. Tank operating pressure shall be 150 pounds per square inch. Provide 150-pound ANSI raised face flanges.~~
- ~~C. The separator shall be designed with tangential entry into the acceptance chamber. Upon tangential entry, the liquid/solids are drawn through internal tangential slots and accelerated into the reduced diameter separation cylinder. The solids heavier than the carrying liquid are centrifugally spiraled down the perimeter of the separation cylinder past the deflector stool and allowed to accumulate into the separator's collection chamber. The liquid (free of separable solids) will follow the vortex created and centered on the deflector stool up through the interior of the separator cylinder and into the vortex finder, which becomes the separator outlet.~~
- ~~D. The separator shall incorporate a pressure relief line from the collection chamber to the venturi located in the tangential inlet to enhance separation by facilitating quiescent solids sedimentation in the collection chamber. Quiescent solids accumulation shall also be facilitated by the baffle spin-arrestor below the deflector stool in the collection chamber.~~

~~Separation and collection of solids shall not promote excessive wear nor require a continuous "involuntary" underflow.~~

~~E.The control system shall be pre-piped and pre-wired for automatic separation and purge to clean the solids collector when the differential pressure across the tank increases to a preset point.
Pipe purge line to closed loop liquid recovery tank.~~

~~F.Provide shop coats of primer and finish enamel.~~

~~G.Provide factory supplied wall-mounting brackets or floor stands.~~

PART 3 – EXECUTION

- 3.01 Comply with manufacturer's instruction regarding installation, particular with regard to mounting height above or below operating levels of the cooling tower sump and make-up levels.
- 3.02 Run drain lines to an approved indirect waste.
- 3.03 Protect cyclone separators, filters and piping exposed to below freezing ambient temperatures with factory installed electric heat tape and insulation. Protect the pre-strainer, pump, piping, valves, pressure switch tubing and filter tank.
- 3.04 All interconnections (piping, wiring, control), and interlocks between controls and cooling tower water pumps shall be by Mechanical Division. Provide 2 sets of dry contacts for interface to Building Management System for both the filter and separator.

END OF SECTION

SECTION 23 31 00

DUCTWORK

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
1. Ductwork
 2. Plenums
 3. Fasteners and Sealants
 4. Duct Cleaning
 5. Access Doors
 6. Duct Testing
 7. Installation of Equipment and Materials Furnished Under Other Sections
 8. Duct Drain Piping
 9. Installation of Duct Smoke Detectors

1.02 SUBMITTALS

- A. Submit the following for review:
1. Submit ductwork shop fabrication and shop construction standards prior to submittal of ductwork shop drawings.
 2. Ductwork shop fabrication and shop construction standards shall include all applicable shop details and product data. Include the following:
 - a. Duct reinforcement tables for all pressure classes, duct materials galvanized steel, aluminum, stainless steel, and ductwork shapes rectangular, round, spiral, flat oval to be used on this project
 - b. Duct reinforcement tables shall include material gages, transverse joint reinforcement type and standard shop joint spacing.
 - c. Transfer duct construction detail
 - d. Acoustical lining, perforated metal liner, adhesive, nosing and fastening cuts and details
 - e. Installation details for volume dampers, single blade and multiblade type, remote and cord operated remote volume dampers, control dampers, fire damper installation detail
 - f. Duct access doors
 - g. Duct fitting construction details such as rectangular and radius elbows, turning vanes, offsets, branch connections, etc.
 - h. Duct support and attachment details
 - i. Flanged duct connection details for all systems and each manufacturer used on project. Minimum duct construction gages shall be as per SMACNA duct reinforcement tables. Duct gages may not be reduced based on alternative jointing manufacturer's recommendations.
 - j. Ductwork sealant
 - k. Diffuser ductwork connection details
 - l. Duct penetrating full height partition details
 - m. Flexible connection details
 - n. Duct and plenum construction details
 3. Product Data including manufacturer's installation instructions, application, materials of construction, gauges, descriptive literature, and maintenance data for:
 - a. Ductwork and fittings
 - b. Plenums

- c. Fasteners and sealants
 - d. Access doors
 - e. Chemical resistance of interior duct coatings
4. Shop Drawings:
- a. Fully coordinated ¼-inch scale dimensioned duct layout drawings of all mechanical rooms, riser elevations, and floor plans, giving complete dimensions for location, elevation, and clearance, showing work of all other Sections and Divisions. Layout drawing shall be prepared with architectural floor plan and ceiling grid background indicating room numbers, ceiling heights, location and elevations of structural components, light fixtures, all piping and other equipment.
 - b. ¼-inch scale dimensioned duct layout drawings of all mechanical rooms, riser elevations, and floor plans, giving complete dimensions for location, elevation, and clearance, showing work of other Sections and Divisions wherever necessary to show coordination.
 - c. Access door details
 - d. Flexible connection details
 - e. Duct and plenum construction details
 - f. Dimensioned drawings showing penetrations required for ductwork through structural members, floor and roof slabs, concrete walls and precast walls.
 - g. Duct materials, reinforcement and construction schedules
 - h. Duct support and attachment details
5. All sheet metal shop drawings shall be drawn in double line indicating actual dimensions of ductwork, fittings and equipment. Shop drawings submitted with ductwork drawn in single line shall be returned without review.
6. Sheet metal shop drawing shall indicate, as a minimum, the following data:
- a. Ductwork sizes and section breaks
 - b. Location of acoustical lining
 - c. Bottom of duct elevations for all ducts or other services in conflict with ductwork
 - d. Diffuser face size, neck size and air quantity
 - e. All volume dampers
 - f. All air conditioning units
 - g. All terminal units
 - h. Dimensioned drawings showing penetrations required for ductwork through structural members, floor and roof slabs, concrete walls and precast walls
 - i. Duct support and attachment details
7. HVAC design drawings shall not be submitted as sheet metal shop drawings.
8. Prior to mounting or hanging of mechanical equipment or ductwork, obtain approval from Architect for proposed method of mounting particularly in existing buildings. Submit weights and location of all mechanical equipment and ductwork to the Architect for approval well in advance of general construction work to allow sufficient time for any structural evaluation, critique and necessary redesign to accommodate the installation.

1.03 REFERENCE STANDARDS

- A. The latest editions of specifications standards, tests or recommended methods of trade, industry or governmental organizations apply to work in this section where cited below:
 - 1. ASHRAE – American Society of Heating, Refrigeration and Air Conditioning Engineers Handbooks (Latest Editions)
 - 2. SMACNA – Sheet Metal and Air Conditioning Contractors National Association, Inc.:

- a. HVAC Duct Construction Standards, Metal and Flexible, Second Edition, 1995 with Addendum 1 dated November 1997
 - b. Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems, Fourth Edition, 1992
 - c. HVAC Systems Testing Adjusting and Balancing
 - d. Seismic Restraint Manual Addendum dated November 1993
 - e. HVAC Air Duct Leakage Test Manual 1st Edition
3. UMC – Uniform Mechanical Code, Standard 6-2: Standard for Metal Ducts, Latest Edition
 4. AABC – Associated Air Balance Council Manual: National Standards for Total System Balance
 5. ANSI – American National Standard Institute
 6. NFPA – National Fire Protection Association Standards:
 - a. NFPA 90A, Installation of Air Conditioning and Ventilating Systems
 - b. NFPA 90B, Warm Air Heating and Air Conditioning Systems
 - c. NFPA 96, Exhaust Systems
 7. UL – Underwriters’ Laboratories, Standards for Safety: UL 181, UL 555 (Fire Dampers and Ceiling Dampers) UL 555S (Leakage Rated Dampers for Use in Smoke Control Systems)
 8. ACGIH – American Conference of Governmental Industrial Hygienists: Industrial Ventilation – A Manual of Recommended Practice
 9. UBC – Uniform Building Code
 10. The State of Washington Codes.
 11. Local Codes.
- B. Above-referenced standards may be superseded by notes and details on drawings and in any specification.
- C. Where two or more references conflict, the most stringent, as determined by Architect shall take precedence.

1.04 DUCT CLASSIFICATION

- A. Duct classification is based on pressure classification as scheduled in Table 1-1 and as described in the 1995 SMACNA HVAC Duct Construction Standards (Metal and Flexible). Comply with NFPA 90A when ducts traverse through smoke zones. Comply with UBC/UMC when more stringent than NFPA 90A or SMACNA standards.
- B. Longitudinal Seams: Pittsburgh lock shall be used on all longitudinal seams, Snap-lock or button punch seams are not acceptable. If SMACNA seal class A or B is specified, the longitudinal seam shall be sealed from the inside.
- C. Minimum pressure classification for each duct system and appropriate SMACNA table references are as follows:

| Duct System | SMACNA Table No. | SMACNA Pressure Classification (inches water gauge) | SMACNA Seal Classification |
|---|------------------|---|----------------------------|
| All rectangular supply ducts on systems with variable or constant volume terminal units from fan discharge to terminal unit | 1-6 | ±3 | A |
| All rectangular supply ducts on systems without terminal units from fan discharge to air outlet | 1-5 | ±2 | B |

| Duct System | SMACNA Table No. | SMACNA Pressure Classification (inches water gauge) | SMACNA Seal Classification |
|--|------------------|---|----------------------------|
| All rectangular ductwork downstream of terminal units All rectangular return ducts and exhaust ducts, where not used for smoke exhaust | 1-4 | ±1 | B |
| All rectangular return ducts and exhaust ducts where used for smoke exhaust | 1-6 | ±3 | A |
| All round supply ducts on systems with terminal units from fan discharge to terminal unit and parts of smoke exhaust systems under positive pressure | 3-2A | +4 | A |
| All round supply ducts on systems without terminal units from fan discharge to air outlet, and all ductwork downstream of terminal units to diffusers and parts of return or exhaust ducts under positive pressure | 3-2A | +2 | B |
| All round return ducts and exhaust ducts, where not used for smoke exhaust and parts of supply system under negative pressure | 3-2B | -2 | B |
| All round return ducts and exhaust ducts where used for smoke exhaust and parts of a supply system under negative pressure | 3-2B | -4 | A |

- D. Duct classification is applicable to all ductwork and associated sheet metal work except for the following:
1. Grease, fume and vapor exhaust systems
 2. Field-constructed or factory fabricated plenum partitions

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Spiral Oval and Round Ducts: United McGill “Uni-form”, Semco, Metco, Ductmate Industries “Spiralmate” and “Ovalmate”
- B. Duct Connection Systems: Ductmate Industries “Ductmate 35” and “Ductmate 45”, Nexus, Ward
- C. Flexible Connections: Ventfabrics “Ventglas” and “Ventlon”, Duro Dyne “Insulfab”, Advance Elastomeric Systems, Ductmate Industries “PROFlex”
- D. Flexible Ducts: Automatic Industries “Thermafex MKE”, United McGill, Wiremold “WG”, Genflex “IL”

~~E. Fiberglass Ducts and Hardware: Owens-Corning Fiberglass, Certain-Teed, Manville, Duro Dyne “Glasline”~~

~~F. Underground Ducts: Manville, United McGill, Peabody “Spunstrand FSK”~~

~~G. Underground Tunnels: Armco “Smooth-Flo”~~

- E. Spring Fasteners: Dzus, Simmons "Quick-Lock"
- F. Duct Protective Coatings: Wisconsin Protective Coating, Varni-lite of America
- G. Duct Sealants: Minnesota Mining and Manufacturing, Benjamin Foster, Miracle Adhesive, United McGill, Hardcast, Ductmate Industries "PROSeal"
- H. Spin-in Fittings: Young Regulator, Modular Metals
- I. Flexible Duct Clamps: Aeroquip Ideal, Tridon, Young Regulator
- J. Acoustical Panel Plenums: IAC, Rink, Vibro-Acoustics, United McGill
- K. Access Doors, Ducts: Ventfabrics, Duro Dyne, Ruskin. Use "Ventlok" No. 130 latches, Ductmate Industries, hinged type only
- L. Access Doors, Plenums: Ventfabrics, Duro Dyne, Elgen
- M. Duct Joint Tape: Hardcast
- N. Double Wall Duct: United McGill "Acousti-K27"
- ~~R. Grease Exhaust Duct Gasket: Ventfabrics "Wire-Inserted Glass Cloth"~~
- O. Plastic Coated Duct: United McGill "Uni-Coat"
- P. Pressure Relief Panels: Ruskin PRD18, United McGill ARR or ASR

2.02 MATERIALS

- A. Sheet Metal:
 - 1. Steel Sheets:
 - a. Cold rolled steel sheets, lock forming quality meeting ASTM A-653 and A-653M
 - b. Black or galvanized as specified
 - c. Galvanizing: 1¼ ounces per square foot both sides
 - 2. Stainless Steel Sheets: ANSI Type ~~316~~ 304 as specified, with Finish No. 2B or No. 3
 - ~~3. Lead Sheets: Federal Specification QQ-L-301a, Grade C., 6 millimeters thick~~
 - 3. Aluminum sheets: ASTM B209, maximum 0.4 percent copper. Provide mill-finish commercial sheets; 16,000 pounds per square inch minimum strength.
- B. Miscellaneous Products:
 - 1. Screws and Rivets:
 - a. Same material as sheet, except as noted.
 - b. Zinc or cadmium plated with neoprene grommets, permitted on galvanized sheets.
 - c. Minimum screw size: No. 10
 - d. Minimum rivet size: 4 pound
 - 2. Duct Sealants:
 - a. Sealing compound shall be flexible water-based adhesive sealant designed for use in all pressure classes. Sealant shall be UV-resistant, conform to

- AST4 E84, be UL 723 listed and meet NFPA requirements for Class 1 ductwork.
- b. Flange Gasket: Provide a continuous butyl rubber gasket which complies with UL Standard 181 and 723 testing and meets MIL-C 18969B and TTS-S-001657. This material shall not contain vegetable oils, fish oils, or any other type of materials that will support fungal or bacterial growth. Gasket width shall match duct flange or angel connection with a minimum thickness of 1/8 inch. Ductmate Industries Model 440 gasket tape or approved equal.
 - c. Liner Adhesive used to adhere insulation to metal duct shall comply with NFPA 90A and UL 723 specifications. Ductmate Industries PROtack Liner adhesive or approved equal.
 - d. Lagging Adhesive shall be applied to insulated ductwork where the insulated edge of the duct would otherwise be exposed to the airflow. Materials shall comply with ASTM E 84, NFPA 255 or UL 723 testing. Ductmate Industries Lag-It or approved equal.
3. Hard-setting joint tape shall be a UL listed two-part tape consisting of woven fiber tape impregnated with activator/adhesive of polyvinyl acetate type.
 - a. Flame spread: 10 maximum
 - b. Smoke developed: 0
 4. Spring Fasteners: Self-ejecting oval head stud and receptacle with screwdriver slot.
 5. Provide angles, tie rods and structural steel shapes for reinforcing ducts in accordance with SMACNA HVAC Duct Construction Standards, except as noted.
 6. Slide-on Transverse Joint Connectors:
 - a. Prefabricated slide-on transverse duct connectors and components shall be accepted. Ducts constructed using prefabricated systems shall refer to the manufacturer guidelines for sheet gauge, intermediate reinforcement size and spacing, and proper joint reinforcement. Ductmate Industries, Ward, Nexus, or approved equal.
 - b. Formed-on flanges shall be constructed as T-25 A/B flanges, of which the construction guidelines are given in Figure 1-4 of the 1995 SMACNA HVAC Duct Construction Standards, Metal and Flexible, Second Edition. No other construction standards pertaining to formed-on flanges shall be accepted.
 - c. Formed-on flanges shall include the use of corners, bolts, cleat and gasket.
 - d. All components shall be metal unless other materials are required by code or specified.
- C. Flexible Connections shall be used where ductwork connects to rotating, vibrating or noise producing machinery. Connectors shall be attached in such a manner to provide an airtight and waterproof seal.
1. Conform to UL 214, NFPA 90A and SMACNA HVAC Duct Construction Standards, except as noted.
 2. Provide roll formed 1½-inch long minimum or match length and width of fan, plenum or machinery connection companion flange:
 - a. Aluminum, 1 gauge heavier than ductwork, plenum, fan or machinery connected.
 - b. Galvanized steel, 26 gauge minimum or matching gauge of ductwork, fan, plenum or machinery connected.
 - c. Other materials same as gauge and material as ductwork, plenum, fan or machinery connected.
 3. Provide 2-inch slack in fabric and install to allow minimum movement of 1 inch.
 4. Length of fabric connections: 4 inches minimum; 10 inches maximum.
 5. Materials:

- a. Indoor installations shall be a UL listed, fire retardant neoprene or vinyl coated woven fiberglass fabric. Minimum density 30 ounces per square yard and rated to 200° F.
- b. Outdoor installations shall be a UL listed ultra violet light resistant Hypalon coated woven fiberglass fabric. Minimum density 24 ounces per square yard and rated to 250° F.
- c. Flame spread rating: 25 maximum, smoke developed rating: 50 maximum
- d. Insulated connections:
 - (1) Two layers of fabric with 1-inch thick fiberglass, 1.5 pound density.
 - (2) Performance as previously specified in 2.2-C-5-b.
- e. Provide wire embedded uncoated glass fabric with sewn seams for air temperature over 150° F.

D. Turning Vanes:

- 1. Galvanized steel ductwork: galvanized steel or painted black steel, except as noted.
- 2. Other ductwork: Same material as ductwork.
- 3. Construction shall meet or exceed SMACNA "HVAC Duct Construction Standards".
 - a. Use of single wall vanes with ¾-inch trailing edge shall be limited to maximum air velocity of 2000 feet per minute and a maximum duct dimension of 18 inches.
 - b. Double wall vanes shall be used in ducts where air velocity exceeds 2000 feet per minute or any duct dimension over 18 inches.
 - c. Vane length: Provide separate equal size sections for vane length greater than those previously indicated in 1.04: Referenced Standards.
 - d. Vane runners: SMACNA Type 1 or 2 acceptable.
 - e. Tab spacing shall be as specified in Figure 2-3 of the 1995 SMACNA Manual, HVAC Duct Construction Standards, Metal and Flexible, Second Edition. Rail systems with non-standard tab spacing shall not be accepted.

E. Rectangular main duct to round duct take-off fittings shall be factory-fabricated spin-in fittings.

- 1. Die-formed, same material as ductwork.
- 2. Pressure ratings shall be equal to the duct pressure rating in which they are installed.
- 3. Provide balancing damper with locking regulator.

2.03 ROUND AND OVAL DUCTWORK

A. General:

- 1. Provide factory-fabricated spiral lockseam duct, except as otherwise indicated.
- 2. Factory-fabricated longitudinal seams are acceptable for ducts larger than standard factory sizes and are required where branch sizes, fitting sizes, air inlet or outlet sizes exceed the seam-to-seam dimension.
- 3. Round and oval ducts joints shall be constructed as follows:
 - a. Up to 20-inch equivalent diameter: Interior slip coupling beaded at center and fastened to the duct with screws. Seal joint with approved sealant continuously applied around joint prior to assembly and after fastening. Make certain that majority of sealant is on the interior of the joint.
 - b. From 21-inch to 72-inch equivalent diameter: Use joining system as described in a. above or join using a three piece gasketed flanged joint consisting to two internal flanges, with integral mastic sealant and one external closure band which compresses the gasket between the internal flanges similar to Ductmate Industries "Spiralmate" or "Ovalmate" or

- approved equals.
 - c. Greater than 72-inch equivalent diameter: Join using companion angle flanged joints as defined in figure 3-2 of the 1995 SMACNA Manual "HVAC Duct Construction Standards, Metal and Flexible" Second edition. Duct wall shall be a continuously welded longitudinal seam.
4. Factory-fabricated fittings shall be same manufacturer as duct and the same material and construction as duct in which installed.
- a. Tees: 45° conical tap with center-line take-off, unless otherwise indicated. Provide continuously welded seams.
 - b. Elbows:
 - (1) Segmented seams or standing segmented seams.
 - (2) Continuously welded for positive or negative 2-inch water gauge and greater:
 - (a) 2 gores – less than 35°
 - (b) 3 gores – 36° through 71°
 - (c) 5 gores – over 71° to 90° maximum
 - c. For ducts listed below, the following are acceptable:
 - (1) Die-stamped radius elbows for ducts 8 inches or smaller.
 - (2) Segmented elbows as specified above for ducts larger than 8 inches.
 - (3) Not acceptable:
 - (a) Corrugated or flexible metal duct
 - (b) Pleated elbows
 - (4) Adjustable elbows are acceptable only for:
 - (a) Downstream of VAV terminals, heat pumps, fan coil units and packaged air conditioning units
 - (b) Portions of exhaust systems and return systems under negative pressure not to exceed 1-inch water gauge
- B. Single-Wall Ducts:
- 1. Materials of construction:
 - a. Galvanized steel: Supply and return, general and toilet exhaust ducts, laboratory exhaust trunk ducts.
 - b. Type 304 316 stainless steel:
 - c. Laboratory and fume exhaust branch ducts.
- C. Double-Wall Ducts:
- 1. Factory-fabricated double-wall duct
 - 2. Outer duct: materials and gauges specified above for single-wall duct
 - 3. Fibrous glass insulation
 - a. 2-inch thick
 - b. Thermal conductivity: 0.27 BTUH/inch/square foot degree F at 75° F
 - c. Flame spread: 10-20 maximum
 - d. Fuel contributed: 10-15 maximum
 - e. Smoke developed: 0-20 maximum

4. Inner duct:
 - a. Perforated for all ducts except those ~~specified below~~ shown on drawings.

D. Factory-Fabricated Accessories:

1. Couplings
2. Volume dampers
3. Bellmouth fittings
4. End caps
5. Angle rings
6. Insulation ends: Connections of double to single wall ducts
7. Access doors: Hinged, framed or pressure relief per SMACNA "HVAC Duct Construction Standards" Fig. 2-10

2.04 FLEXIBLE DUCTS

A. General:

1. Provide UL 181, Class I air duct with polymeric liner, labeled for compliance with UMC. Use only where indicated.
2. Flexible ducts shall meet criteria as defined in Section 3 of the 1995 SMACNA Manual, HVAC Duct construction Standards, Metal and Flexible, Second Edition or as specified

B. Static Pressure Class up to 1-Inch Water Gauge.

1. Insulated Flexible Duct:
 - a. Maximum working pressure 1-inch water gauge
 - b. Nominal 1 inch insulation with vapor barrier
 - c. Maximum thermal conductivity 0.27 BTUH per square foot per degree F per inch at 75° F
2. Similar to Wiremold Type WG
3. Use at air inlets and air outlets

C. Static Pressure Class Over 1-inch up to 10 Inches Water Gauge:

1. Insulated Flexible Duct:
 - a. Maximum working pressure 10 inches water gauge
 - b. Nominal 1½-inch resilient glass fiber insulation with flexible vapor barrier jacket and wire reinforced inner core
 - c. Maximum thermal conductivity of 0.27 BTUH per square foot per degree F per inch at 75° F.
 - d. Maximum length: 12 inches
 - e. Maximum offset: 2 inches
2. Use at inlet connections to variable or constant volume terminal units, sized to match terminal unit.
3. Similar to Wiremold type WK

D. Provide factory fabricated collar.

E. Flexible ductwork clamps shall be adjustable screw type stainless steel straps approved for use with flexible ductwork.

- F. Regenerative noise due to air turbulence with the flexible duct shall not exceed the following sound power levels for a 12-inch diameter duct with an air speed of 1,000 feet per minute:

| | Sound Power Levels, dB re: 10 ⁻¹² Watts, at Octave Band Center Frequency, Hz | | | | |
|----------------------------|--|-----|-----|------|------|
| | 125 | 250 | 500 | 1000 | 2000 |
| Maximum Regenerative Noise | 30 | 31 | 30 | 22 | 20 |

2.05 FUME EXHAUST DUCTS

- A. Type ~~316~~ 304 extra low carbon (ELC) stainless steel welded airtight.

2.06 ACCESS DOORS

- A. Access doors shall comply with the 1995 SMACNA – Duct Construction Standards, except as noted.
- B. Duct access doors shall be insulated or uninsulated, same as duct. Make completely accessible.
1. Minimum Size:
 - a. 20 inches by 14 inches, 18 inches by 16 inches or larger.
 - b. Ducts less than 16 inches: one dimension 20 inches; other dimension 2 inches less than duct width or height.
 - c. Larger sizes where required for access.
 2. Systems designed for 2-inch water gauge and less (SMACNA Seal Class B or C) shall utilize a hinged and cam, square framed access door.
 3. All other systems shall utilize a hinged access door. Construct door in accord with Figure 2-10 of the 1995 SMACNA Manual “HVAC Duct Construction Standards, Metal and Flexible” second Edition.
 4. Provide in following locations:
 - a. Coils in ducts: entering and leaving side
 - b. Automatic dampers: linkage side
 - c. Balancing dampers and backdraft dampers
 - d. Fire dampers, smoke dampers and combination fire/smoke dampers
 - e. Duct-mounted smoke detectors, sprinkler heads, heat detectors
 - f. ~~Duct humidifiers~~
 - f. Filter banks in ducts
 - g. Fan bearings enclosed in ducts
 - h. Inlet side of each single width centrifugal fan
 - i. Inlet and outlet sides of each in-line centrifugal and axial fan or sound attenuator
 - j. All controls, sensing, processing, transmitting and actuating devices
 - k. Duct drains
 5. Provide permanent label on all access doors identifying the concealed components as specified above.
- C. Casing and Plenum access doors shall be uninsulated or insulated, same as casings and plenums.
1. Latches similar to Ventlok No. 202
 2. Minimum size: 24-inch by 60-inch
 3. Provide larger size where required for equipment access, service, maintenance, removal and replacement.

4. Provide in following locations:
 - a. Fan or equipment enclosures
 - b. Coil and filter banks
 - ~~c. Humidifier dispersion tubes and grids~~
 - ~~d. Moisture eliminators and air blenders~~
 - c. Fire alarm devices, sprinkler heads
 - d. Dampers
 - e. All VFDs, controls, sensing, processing, transmitting and actuating devices
 5. Doors to open against pressure.
- D. Glass Inspection Panels:
1. Wired safety glass, gasketed and watertight.
 2. 12-inch by 12-inch, except as noted or specified.
 3. Provide in access doors, or where specified or indicated on the Drawings.

PART 3 – EXECUTION

3.01 DUCTWORK INSTALLATION

A. General:

1. Construct with gauges, joints, bracing, reinforcing, and other details per latest UMC, SMACNA, or NFPA unless specified otherwise. Comply with most stringent.
2. Ductwork shall not exceed the deflection limits established in UMC Standard 6-1-Standard for Metal Ducts, 1997 Edition. Maximum allowable deflection for transverse joints and intermediate reinforcements shall not exceed 0.25-inch for duct widths up to 100 inches and shall not exceed 0.3% of the span for duct widths greater than 100 inches.
3. Construct ducts with NFPA 90A gauges when traversing smoke zones.
4. Construct of galvanized sheet metal, except where otherwise indicated or specified.
5. Duct dimensions indicated are net, inside, clear, dimensions. For internally lined ducts, add lining thickness to determine metal duct dimensions.
6. At exposed duct penetrations of walls, floors and ceilings, provide sheet metal angle type escutcheons fastened to the duct only.
7. Provide minimum 26-gauge sheet metal construction for ducts crossing fire rated corridors. Refer to Architectural drawings for wall types and ratings.
8. Install exposed ducts as high as possible but within 48 inches of ceiling. Coordinate with other trades to maintain not less than 90 inches clearance above finished floor, unless indicated otherwise.
9. Transitions: Pitch sides of duct in “diverging” or “converging” airflow.
 - a. Maximum of 15°-included angle.
 - b. Exception: Provide 7½° concentric diverging velocity cones at the discharge of vane axial fans.
10. Duct Openings: Provide openings where required to accommodate thermometers, smoke detectors, controllers, wiring, conduit, tubing etc. Insert through airtight rubber grommets.
 - a. Provide pitot tube openings where required for testing of systems:
 - (1) Include threaded metal cap, spring loaded cap or threaded plug to eliminate any air leakage.
 - (2) For Pitot tube tests install Ventlock No. 699 and 699-2 instrument

- test holes.
 - (3) Coordinate locations of openings with balancing contractor.
 - b. Where openings are provided in insulated ductwork for insertion of instruments, install insulation material metal sleeve, flanged on one end for use as plug. Reseal vapor barrier.
 - 11. Duct lining: Install lining in ducts and plenums as specified in Section 23 33 19: Acoustics.
 - 12. Flexible Duct Connections.
 - a. Install:
 - (1) At connections to fans, sound attenuators, generator fan discharge, fan coils, heat pumps, air conditioning units and all air handling equipment.
 - (2) As indicated on Drawings or specified in other sections.
 - 13. Refer to SMACNA duct construction standards for outdoor flexible connection details.
 - 14. Volume dampers:
 - a. Install damper as specified in Section 23 33 13: Dampers and Section 23 37 00: Air Outlets and Inlets.
 - b. Install damper in branch duct for all air inlets and outlets at accessible location most remote from air inlet or outlet.
- B. Elbows:
 - 1. Use radius elbows in rectangular ducts unless otherwise indicated. Centerline radius shall be a minimum of 150% of duct width.
 - 2. Where space does not permit duct radius specified above, install short radius or square elbow with vanes per SMACNA duct construction standards.
 - a. Fume hood exhaust
 - b. Breeching
 - c. Toilet exhaust ducts
 - d. Any gravity ductwork
 - 3. For 2-inch water gauge or above pressure class ductwork, spot weld turning vanes to duct.
 - 4. For all 2-way splits in supply, return and exhaust systems, provide 2 elbows, proportionally sized per SMACNA Duct Standards, either radius or square. A single fitting is acceptable with turning vanes and duct openings sized as specified.
- C. Rectangular Duct Joints and Seams:
 - 1. Provide standing, longitudinal seams, except where flush drive slip seam is specified.
 - 2. Use grooved seam for exposed ducts except in garages, electrical or mechanical rooms, and where required for clearance.
 - 3. "Duct Connection System" joints, may be used in lieu of standing seams. Plastic clips are only allowed for breakaway connections.
 - 4. Fabricate ductwork and coordinate installation such that seams or joints shall not be cut or interrupted for the installation of branches, fittings, dampers, access doors, air inlets or air outlets.
- D. Joint Sealing:
 - 1. Seal to SMACNA Seal Classifications previously specified by one of the following

methods:

- a. 6-ounce canvas strip, 6 inches wide adhered with lagging adhesive.
 - b. Hardcast PC-S tape (Duct Tape Not Allowed) and United Hi-Velocity sealer.
 - c. Applications as recommended by manufacturer.
2. Seal punched holes and corner cracks (Duct Tape Not Allowed).
 3. After installation and testing reseal joints found to be leaking.

E. Ducts Out-of-Doors:

1. Ducts shall be watertight.
2. Construct as follows to assure water run-off and no standing water.
 - a. Arrange standing seam, internal reinforcement, joints, flanges and access doors to prevent accumulation, ponding or pooling of water for both horizontal and vertical ductwork.
 - b. Locate longitudinal seams at bottom of duct.
 - c. Slope entire top of duct down toward sides. Coordinate duct slope with roof slope to avoid situations where roof slope and duct slope cancel each other out resulting in an unsloped top of duct.
 - d. Provide mastic within sheet metal joints.
3. Installations and penetrations shall be in accordance with SMACNA Guidelines for Roof Mounted Outdoor Air-Conditioner Installations.
4. Provide sheet metal flashing or skirt at flexible connections to fans or HVAC units to avoid water accumulation.
5. Coordinate exact duct routing and duct support locations on roofs with roofing contractor. Roof-mounted duct support details shall be approved by the roofing contractor and the Architect prior to fabrication and installation.

F. Sound-Rated Duct Packing:

1. Wherever possible avoid duct penetrations through sound-rated walls, floors and ceilings, in either Architectural elements or plenums specified under this section.
2. Provide packing specified in Section 23 33 19: Acoustics for ducts penetrating sound-rated walls, floors or ceilings, and for unavoidable duct penetrations.
3. Any interior walls, floors or ceilings that are internally insulated are considered sound-rated. Refer to Architectural Drawings for wall, floor and ceiling types.

~~G. Stainless-Steel Humidifier Ductwork:~~

- ~~1. Stainless steel sheets as specified with the same gauge as galvanized steel as specified. Joints and seams shall be all welded with all welds pickled to remove weld oxide. Passivate surfaces after welding to remove embedded foreign material.~~
- ~~2. Supply duct section 10 feet downstream and 2 feet upstream from humidifier shall be stainless steel, Type 316 extra-low carbon (ELC).~~
- ~~3. Slope upstream and downstream duct 1/2 inch per foot down towards humidifier and provide a drained trough at low point of section. Slope trough to duct drain connection on one side to ensure complete drainage with no evidence of standing water.~~
- ~~4. Provide high temperature resilient rubber grommets for humidifier and condensate return piping to ensure an airtight seal at duct penetrations.~~
- ~~5. Provide watertight access door in side of duct at humidifier.~~
- ~~6. Support humidifier piping independent of duct. Reinforce sidewall where duct penetrations occur.~~

~~H. Lead Shielded Ductwork:~~

- ~~1. Ducts penetrating lead shielded walls.~~

- a. ~~_____ X-Ray and similar rooms~~
- b. ~~_____ Extent as indicated on Drawings~~

[OR]

- c. ~~_____ Minimum extent. [Determine from layout and specify here.]~~

2. ~~_____ Shielding construction, materials and equipment.~~

- a. ~~_____ Conformance with applicable requirements of National Bureau of Standards, Handbook 60, Medical X-Ray Protection.~~
- b. ~~_____ Shielding installed in such a manner that X-Ray protection at any point is not less than above requirements of adjacent lead protection.~~

3. ~~_____ Lead sheets shall be same thickness as in adjoining wall and securely installed, free of waves, lumps or wrinkles.~~

4. ~~_____ Joints:~~

- a. ~~_____ As few as possible.~~
- b. ~~_____ Provide X-Ray absorption equivalent to wall shielding.~~
- c. ~~_____ Solder joints shall form complete continuous seal with smooth finish and a minimum 1-inch lap.~~

5. ~~_____ Hangers: Provide rod type, trapeze hangers 60 inches on center. Rod shall be sized per SMACNA.~~

I. ~~_____ Electrostatic Shielding:~~

- 1. ~~_____ Provide shielding for ducts penetrating electrostatically shielded walls.~~
- 2. ~~_____ Shielding shall be electrically discontinuous through a nonconductive flexible connection located outside of shielded room.~~
- 3. ~~_____ Bond metallic portion of duct inside shielded room to wall shielding.~~
- 4. ~~_____ Sheet lead in contact with concrete, mortar or plaster shall be coated with heavy bituminous or latex material.~~
- 5. ~~_____ Joints shall be minimum 1 inch.~~

3.02 ROUND AND OVAL DUCTWORK

A. Joints between ducts:

- 1. Construct with beaded sleeve joints.
- 2. Mechanically fasten with sheet metal screws or pop rivets except for fume exhaust, dust collection, clothes dryer ductwork.
- 3. Duct sealer shall be applied to male end and over all joint, screw and rivet heads.
- 4. Seal as specified for rectangular ductwork.

B. Joints, duct and fitting:

- 1. Slip projecting collar of fittings into duct with a minimum insertion length of 2 inches.
- 2. Apply duct sealer. Seal as specified for rectangular ductwork.
- 3. Mechanical fastener schedule:

| Duct Diameter | End Lap | No. of Rivets/Screws in Slip Joint |
|----------------|---------|------------------------------------|
| 8 inches | ¾-inch | 4 |
| 9 to 16 inches | 1-inch | 6 |
| 17 inches & up | 1¼-inch | 7 plus 3 per inch of circumference |

| Duct Diameter | End Lap | No. of Rivets/Screws in Slip Joint |
|---------------|---------|---------------------------------------|
|---------------|---------|---------------------------------------|

C. Junctions between ducts:

1. Branch take-off: 45°

[OR]

~~2.Branch take-off: conical 90°~~

~~3.Branch connections to unlined rectangular ducts may be made with spin in fittings as specified.~~

D. Horizontal supports shall be one piece clamp band strap, minimum one strap per section. Support fittings as required by SMACNA.

E. Vertical supports shall be one of the following:

1. Clamp bands with extended ends supported at each floor.
2. Clamp bands with knee bracing.
3. Pedestal at base of vertical riser.

F. Use angle iron braces for duct reinforcing. Refer to the SMACNA HVAC Duct Construction Standards figure numbers 1-9 thru 1-12.

G. Additional bracing:

3.03 FLEXIBLE DUCTWORK

A. Provide continuous, single pieces.

B. Maximum Length:

1. Above 1-inch water gauge static pressure: 12 inches or as specified.
2. Under 1-inch water gauge static pressure: 6 feet.
3. Local codes or union rules take precedence and may reduce the maximum lengths specified.

C. End Connections:

1. Connect to duct collars, terminal unit connections and round air outlets per manufacturer's instructions.
2. Secure with strap clamps specified above.

D. Installation:

1. Support per SMACNA.
2. Flexible duct is not allowed in lengths greater than that specified. Bends, twists or sagging of flexible duct is not acceptable.
3. Minimum inside bending radius shall be a minimum of two duct diameters. If minimum radius cannot be maintained provide sheet metal plenum over air outlet and connect flexible duct to side of plenum. Paint interior flat black.
4. Maximum – one 90° turn.
5. Install as straight as possible.

E. Flexible duct is only allowed above lay-in type accessible ceilings only.

3.04 FUME HOOD EXHAUST DUCTWORK

- A. Provide stainless steel ductwork fabricated and installed as specified.
- B. Joints shall be Van-Stone flanges with corrosion resistant neoprene gaskets.
- C. Hangers shall not penetrate ducts. Damper shaft penetrations shall be grommetted.

~~D. Interior Coating (Wisconsin Protective Coating Corp. products listed):~~

- ~~1. Coating: Plasite No. 7122~~
- ~~2. Joint Adhesive Sealant: Plasite No. 7122 sealer.~~
- ~~3. Primer: Plasite No. 7103.~~
- ~~4. Preparation:~~

- ~~a. Completely remove oil and grease.~~
- ~~b. Sandblast to white metal finish per SSPC-SPS or NACE-1.~~
- ~~c. Spray on coating same day as sandblasting.~~
- ~~d. Apply one coat of inhibiting primer.~~
- ~~e. Apply two spray coats of coating.~~

- ~~(1) Each coat 6 mil thick, dry.~~
- ~~(2) First coat white.~~
- ~~(3) Second coat black.~~

- ~~f. Allow curing as per manufacturer's requirements at 70 degrees F.~~

~~5. Other.~~

3.05 DUCT HANGERS AND SUPPORTS

- A. General:
 - 1. Support horizontal ducts with hangers of size and spacing as indicated in SMACNA Duct Construction Standards.
 - 2. Attachment to structure shall be as specified in Section 23 04 29: Supports, Hangers, Anchors and Sleeves.
 - 3. Vibration isolation and seismic restraints for ducts shall be as specified in Section 23 05 48: Vibration Isolation and Seismic Restraints.
 - 4. Seismic restraints shall comply with SMACNA or UMC, whichever is more stringent.
- B. Horizontal Duct Supports:
 - 1. Install hangers at each change in direction of duct.
 - 2. Strap hangers:
 - a. Extend strap down both sides of ducts.
 - b. Turn under bottom two inches minimum. Provide a minimum of 2 screws per side.
 - c. Screw hangers to bottom, upper and lower sides of ducts at 12 inches on center maximum.
 - d. Seal all screw penetrations of ductwork.
 - 3. Angle hangers:
 - a. Per SMACNA Guidelines for Seismic Restraints.
 - b. Seal all penetrations of ductwork.

4. Support rectangular fume, vapor and grease exhaust ducts on angle hangers. Do not penetrate duct with fasteners.
5. Support circular fume, vapor and grease exhaust ducts with shop-rolled flat bar bands around duct.
 - a. Bands shall be 16-gauge by 1-inch steel minimum, hot dipped galvanized or prime coated after fabrication.
 - b. Fasten top to hanger rod and bolt bottom of bands.

C. Vertical Duct Supports:

1. Support vertical ducts at every floor.
2. Use angles or channels riveted to ducts. Seal all duct penetrations.
3. Set angles or channels on floor slab or structural steel members placed in opening, unless otherwise noted.

3.06 PLENUM INSTALLATION

A. General:

1. Construct plenums with gauges, joints, bracing reinforcing, and other construction details in accordance with latest SMACNA, unless specified otherwise.
2. Construct with satin finish galvanized sheet metal of lock forming quality.
3. Install hinged access doors where shown, specified, or required for access to equipment for cleaning and inspection. Minimum door dimension 60-inch by 18-inch with 12-inch by 12-inch minimum observation window, per SMACNA Fig. 6-11 or Fig. 6-12. Reinforce door frames with steel angles tied to horizontal and vertical plenum supporting angles.
4. Coat inside of plenums on discharge of air washers, humidifiers and spray coils with two coats of Bitumastic.
5. Slope floor to duct drain as specified.
6. Install sleeves and air-tight sealing grommets or resilient materials for all piping, conduit, tubing, wiring, shafts or other components penetrating plenum walls. Sealing method shall allow movement of component penetrating the wall.

B. Sheet Metal Plenum Construction:

1. Galvanized sheet metal shall be 16-gauge, unless otherwise indicated:
 - a. Galvanized angle bracing riveted or bolted to sheet metal as required.
 - b. Panels shall be cross-broken.
2. Seams shall be 2-inch standing seams, 24 inches on center and staggered at adjacent panels.
3. Reinforcing shall be 2-inch by 2-inch by ¼-inch galvanized angles riveted or bolted to back of sheet metal and perpendicular to the standing seams.
4. Install angles at all floor, wall, and ceiling corners and around openings.
5. Fasten reinforcing components to floors, ceilings and walls on 16-inch centers. Seams and joints shall be sealed with mastic and made airtight.

3.07 MISCELLANEOUS INSTALLATIONS

A. Install the following equipment and materials furnished under other sections. Comply with manufacturer's installation instructions, code requirements, UL listing and the requirements of local authorities.

1. Backdraft and balancing dampers
2. Fire, smoke, and fire/smoke dampers
3. Control dampers, automatic louver dampers

4. Filters
5. Sound traps
6. Air blenders and moisture eliminators
7. Air monitors and flow measuring devices
8. Access doors. Allow for adequate length of duct to install access door for all dampers.
9. Smoke detectors, flow switches, controls and fire alarm devices
10. Pressure, temperature, humidity sensors/transmitters
11. Humidifiers

B. Duct Drains:

1. Provide a 1-inch Type L copper drain connection at low points for moisture collection.
2. Provide an S-trap (or P-trap) for water seal. Minimum depth of trap shall be 1¼ times maximum static pressure differential in duct section. Trap shall be tapped to accept a ½-inch trap primer connection.
3. Install piping from duct drain to nearest plumbing floor drain or floor sink. Terminate with 1-inch minimum air gap.
4. Provide tee connection in drain between duct and trap.
5. Connection from trap primer shall be furnished under Plumbing Section.

3.08 DUCT AND PLENUM PRESSURE TESTING

A. Scope of Pressure Testing:

1. Test ductwork, including plenums, as scheduled below, for leaks. Pressure testing shall include applicable supply, return and exhaust systems.
2. Apply positive pressure test to all ducts intended to operate under positive pressure of 2 inches water gauge or greater, such as:
 - a. Supply ducts from fans to air outlets
 - b. Supply ducts from fans to air terminal units
 - c. Discharge ducts from exhaust fans outside
 - d. [Others].
3. Apply Positive pressure test to all ducts intended to operate under negative pressure, such as:
 - a. Return ducts from air intakes to fans except on portions of duct exposed in spaces served by duct
 - b. Toilet exhaust ducts from air inlets to fans
 - c. General exhaust ducts from air inlets to fans
 - ~~d. Grease or vapor exhaust ducts from hoods to fans~~
 - ~~e. Grease or vapor exhaust ducts from fans to duct termination point~~
 - d. Fume hood exhausts from cabinets or hoods to fans

B. General:

1. Advise Architect at least 2 weeks in advance of testing so that test can be witnessed.
2. Use portable high pressure blower and necessary instruments. Provide duct connections required for air flow and pressure testing.
3. Test before sections are concealed.
4. Furnish signed reports of results of tests to Architect.
5. Test Pressures shall:
 - a. 150% of scheduled static pressure for fan or unit.

C. Procedure:

1. Seal openings in ducts and plenums to be tested.
 2. Connect test apparatus to test section using flexible duct connection or hose.
 3. Close damper on blower suction side, to prevent excessive buildup of pressure.
 4. Start blower and gradually open damper on suction side of blower.
 5. Test for audible air leaks in ducts and plenums per referenced standards.
 - a. Repair and silence all audible leaks.
 - b. Do not retest until sealants have set.
 6. Test for rate of air leakage in ducts and plenums per referenced standards. Determine amount of air leakage by make-up air flow measurements.
 7. Repair air leaks as required and retest.
 8. Visually mark tested sections with certification sticker and initials of field test inspector.
- D. Ductwork leakage rates shall comply with SMACNA "HVAC Air Duct Leakage Test Manual" 1st edition for leakage Class 6 for rectangular ductwork, and leakage Class 3 for round ductwork.

END OF SECTION

SECTION 23 33 13

DAMPERS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
 - 1. Static and Dynamic Fire Dampers
 - 2. Smoke Dampers and Combination Fire/Smoke Dampers
 - 3. Balancing Dampers
 - 4. Backdraft Dampers
 - 5. Heavy Duty Backdraft Dampers
 - 6. Installation of Automatic Control Dampers
 - 7. Remote Operators for Balancing Dampers

1.02 QUALITY ASSURANCE

- A. Manufacturer: Test and qualify with UL a complete range of damper sizes covering dampers specified. Testing one size only is not acceptable.
- B. Damper shall open and close under HVAC system operating conditions in accordance with UL 555S.
- C. Pressure drop ratings of dampers shall be based on tests and procedures performed in accordance with AMCA 500.
- D. Air Flow Rating: UL approved for dual directional airflow.
- E. Actuator shall have a five-year manufacturer's warranty.

1.03 REFERENCE STANDARDS

- A. AMCA 500 - Test Methods for Louvers, Dampers and Shutters
- B. CSFM - California State Fire Marshall Listing for Fire Damper and Smoke Damper
- C. NFPA 90A - Installation of Air Conditioning and Ventilating Systems
- D. NFPA 92A - Smoke-Control Systems
- E. UL 555 - Standard for Safety; Fire, Smoke and Fire/Smoke Dampers
- F. UL 555S - Standard for Safety; Leakage Rated Dampers for Use in Smoke Control Systems

1.04 SUBMITTALS

- A. Dynamic fire damper submittal shall include performance data developed for UL 555 standard tests. Maximum allowed air flow rate and static pressure for duct and non-duct mounted installations shall be documented.
- B. Submit smoke damper and combination fire/smoke damper schedule indicating size, service, location, number of actuators, and air velocity through the damper.
- C. Submit construction details, hardware details, gauges and certified dimensioned shop drawings for all damper types.

- D. Manufacturer's product data:
1. Include leakage, pressure drop, and maximum pressure data.
 2. Indicate materials, construction, dimensions, and installation details.
 3. Verify conformance to NFPA 90A, NFPA 92A, UL 555, UL 555S, CSFM, and applicable building code.
 4. Verify damper pressure drop ratings based on tests and procedures performed in accordance with AMCA 500.
 5. End switches, wiring diagrams, firefighters relays and override components.
 6. Provide actuator electrical power requirements for both running and holding states and quantities per damper.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Static and Dynamic Fire Dampers: Ruskin DIBD2 Style B, IBD2 Style B, or approved equal by Air Balance, AWW, Pottorff, Greenheck
- B. Smoke Dampers: Ruskin SD60, SD37, SDRS25 (round) or approved equal by Air Balance or Pottorff
- C. Combination Fire/Smoke Dampers: Ruskin FSD60, FSD60-3 (3-hour), FSD 37, FSDR25 (round) or approved equal by Air Balance or Pottorff
- D. Front Access Fire Smoke Dampers: Ruskin FSD60FA or equal by Air Balance or Pottorff
- E. Actuators: Belimo FSNF120, Honeywell ML4115 or equal
- F. Remotely adjustable operators with balancing dampers: Young Regulator Model No. 270-896C and either Model No. 830A-CC rectangular or Model No. 5020-CC round balancing dampers
- G. Backdraft Dampers: Ruskin CBD4 counterbalanced, Ruskin BD2 non-counterbalanced or equal by Air Balance, AWW, Arrow
- H. Heavy Duty Backdraft Dampers: Ruskin CBS92 counterbalanced, or equal by Air Balance, AWW, Arrow
- I. Manual Balancing Damper: Ruskin MD35, MD25, MDRS25, CDO25

2.02 FIRE DAMPERS

- A. Provide static and dynamic fire dampers in ducts penetrating fire rated walls, floors, and ceilings as required by NFPA, local codes and authorities regardless if shown or not shown on the Drawings. Dampers shall be factory marked for static or dynamic use.
- B. Provide conveniently located access doors, of ample size for resetting the dampers. Duct mounted grilles, registers or diffusers can be used for access as long as such access is readily available as determined by the Architect or Authority Having Jurisdiction.
- C. Integral sleeve frame shall be minimum 20-gauge roll formed, galvanized [stainless] steel. Comply with manufacturer's installation instructions and Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Details.
- D. Dampers shall be spring-loaded with shutter stored out of the airstream to provide minimum 95 percent free area.

- E. Dynamic rated fire dampers shall be labeled in accordance with UL 555S. Static fire dampers shall be labeled in accord with UL 555.
- F. Dampers shall be actuated by UL approved fusible link. Upon operation of the link, the dampers shall close automatically and remain tightly closed. Fusible links shall operate approximately 50 degrees F above the maximum temperature the duct system will encounter under normal operation, but not less than 165 degrees F.
- G. Dampers shall be of types acceptable to the local authorities, Owner and Architect.

2.03 FRONT ACCESS FIRE/SMOKE DAMPERS

- A. Provide Class I combination fire/smoke dampers suitable for application in HVAC systems with velocities to 1,000 feet per minute, designed for supply or return ducts with grille outlet and providing through-the-grille access to the damper and heat-actuated components.
- B. Frame: 5 inches by minimum 16-gauge roll formed, galvanized steel hat-shaped channel, reinforced at corners. Structurally equivalent to 13-gauge U-channel.
- C. Factory Furnished Sleeve:
 - 1. Minimum 20-gauge thickness, minimum 12-1/2 inches length with front flange for grille.
 - 2. Equipped with integral access cabinet containing all required accessories.
 - 3. Silicone caulk factory applied to sleeve at damper frame to comply with leakage rating requirement.
 - 4. Provide sufficient sleeve length to accommodate duct connections on nongrille side of opening.
- D. Blades:
 - 1. Style: Horizontal airfoil-shaped, single-piece.
 - 2. Action: Opposed.
 - 3. Material: Minimum 14-gauge equivalent thickness, galvanized steel.
 - 4. Width: Maximum 6 inches
- E. Bearings: Self-lubricating stainless steel sleeve, turning in extruded hole in frame.
- F. Seals:
 - 1. Blade: Silicone rubber edge type for smoke seal to 450 degrees F and galvanized steel for flame seal to 1,900 degrees F. Mechanically attached to blade edge.
 - 2. Jamb: Stainless steel, flexible metal compression type.
- G. Linkage: Concealed in frame.
- H. Axles: Minimum 1/2-inch diameter plated steel, hex-shaped, mechanically attached to blade.
- I. Mounting: Vertical.
- J. Heat-Actuated Temperature Release Device:
 - 1. Control close and lock damper during test, smoke detection, power failure, or fire conditions through actuator closure spring. At no time shall actuator disengage from damper blades.
 - 2. Allow damper to be automatically and remotely resettable after test, smoke detection, or power failure conditions. After exposure to high temperature or fire, inspect damper before reset to ensure proper operation.

3. Controlled closure and locking of damper shall occur in 5 to 15 seconds to allow duct pressure to equalize. Instantaneous closure is not acceptable.
 4. Electric fuse link (EFL) with electric actuators.
 5. Release Temperatures: 165 degrees F
- K. Actuator shall be electric, 120-volt, 60-hertz. Maximum electric power consumption per actuator shall be 0.25 amperes maximum while running and 15 volt-amperes while holding. Controlled closure and locking of damper shall occur within 5 to 15 seconds to allow duct pressure to equalize. Instantaneous closure is not acceptable.
- L. Duct transition connection shall be round, oval or rectangular to match duct configuration.
- M. Factory assemble damper, actuator, sleeve, and accessories and furnish as a single unit conforming to UL 555 and UL 555S.
- N. Performance Data:
1. Elevated Temperature Qualified: Damper and actuator assembly shall be qualified in accordance with UL 555S to elevated temperature of 350 degrees F.
 2. Leakage Class I, when applied in systems with maximum pressure of 4 inches w.g.

2.04 SMOKE DAMPERS, COMBINATION FIRE/SMOKE DAMPERS

- A. Provide dampers of size and location as indicated on the Drawings and as specified.
- B. Frame shall be a minimum of 16 gauge galvanized steel formed into a structural hat channel shape with tabbed corners for reinforcement.
- C. For air velocities up to 1500 feet per minute, the blades shall be single skin 16-gauge minimum galvanized steel with three longitudinal grooves for increased stiffness and reinforcement. For air velocities up to 4000 feet per minute, the blades shall be double skin 14-gauge minimum galvanized steel Bearings shall be a self-lubricating stainless steel sleeve turning in an extruded hole in the frame. Blade edge seals shall be silicone rubber designed to withstand 450 degrees F. Jamb seal shall be silicone impregnated fiberglass with stainless steel flexible metal compression type cover. Maximum blade width shall be 6 inches.
- D. Each damper shall be classified by Underwriters Laboratories as a Leakage Rated Damper for use in smoke control systems under the latest version of UL 555S, and bear a UL label attesting to same. The damper leakage rating under UL 555S shall be leakage Class I (4 cubic feet per minute per square foot at 1 inch water gauge).
- E. In addition to the leakage ratings already specified herein, the dampers and their actuators shall be qualified under UL 555S to an elevated temperature of 350 or 450 degrees F depending upon the actuator. Appropriate listed electric actuators shall be installed by the damper manufacturer at time of damper fabrication. Damper and actuator(s) shall be supplied as a single entity that meets applicable UL 555S qualifications for both dampers and actuators. Provide wiring and conduit materials required to interconnect the actuator(s).
- F. Each damper shall be equipped with indication/position switches consisting of two position indicator switches linked directly to the damper blade to provide the capability of remotely indicating damper blade position.
- G. Smoke damper and combination fire/smoke damper actuators shall be controlled by a 120-volt AC signal from the Division 26 fire alarm system.
- H. Maximum electric power consumption per actuator shall be 0.25 amperes maximum while running and 15 volt-amperes while holding. Controlled closure and locking of damper shall occur within 5 to 15 seconds to allow duct pressure to equalize. Instantaneous closure is not

acceptable.

- I. Electric damper actuator shall be driven open or closed by the rotating motion of a reversible, overload protected non-stall synchronous motor. Crank arm shall be connected to the actuator directly with no intermediate linkage.
- J. Actuator quantities per damper area shall be as recommended by the manufacturer. Provide additional actuators to meet the damper leakage requirement. Damper actuator shall stroke from fully open to fully closed or vice versa in less than 15 seconds from receipt of control signal.
- K. Two position dampers shall have spring return. Provide UL 555S listed and labeled actuators for all dampers.

2.05 ROUND COMBINATION FIRE/SMOKE DAMPERS

- A. Provide Class I round combination fire/smoke dampers suitable for application in HVAC systems with velocities up to 4,000 feet per minute.
- B. Fire Rating: UL 555 classified and labeled as a 1-1/2 hour fire damper.
- C. Smoke Rating: UL 555S classified and labeled as a Leakage Class I Damper for use in smoke control systems: 4 cubic feet per minute per square foot at 1 inch w.g. and 8 cubic feet per minute per square foot at 4 inches w.g.
- D. Air Flow Rating: UL approved for dual directional airflow.
- E. Frame/Sleeve: Minimum 20-gauge galvanized steel with roll formed beads and retaining plate grooves to accept retaining plates for damper mounting.
- F. Blade shall be two-piece, minimum 14-gauge equivalent thickness, galvanized steel.
- G. Bearings: Self-lubricating stainless steel sleeve, turning in extruded hole in frame.
- H. Blade Seals: Silicone rubber fully encompassing the blade edge for smoke seal up to 450 degrees F. Mechanically attached to blade edge.
- I. Axle: Minimum 1/2-inch diameter plated steel, mechanically attached to blade.
- J. Damper and retaining plates shall be one-piece, minimum 20-gauge galvanized steel with factory matched and shipped with individual damper.
- K. Heat-Actuated Temperature Release Device:
 - 1. Control close and lock damper during test, smoke detection, power failure, or fire conditions through actuator closure spring. At no time shall actuator disengage from damper blades.
 - 2. Allow damper to be automatically and remotely resettable after test, smoke detection, or power failure conditions. After exposure to high temperature or fire, inspect damper before reset to ensure proper operation.
 - 3. Controlled closure and locking of damper shall occur in 7 to 15 seconds to allow duct pressure to equalize. Instantaneous closure is not acceptable.
 - 4. Electric fuse link (EFL) with electric actuators.
 - 5. Release Temperatures: 165 degrees F [212 degrees F] [285 degrees F].
- L. Actuator shall be electric, 120-volt, 60-hertz. Maximum electric power consumption per actuator shall be 0.25 amperes maximum while running and 15-volt-amperes while holding. Controlled closure and locking of damper shall occur within 5 to 15 seconds to allow duct

pressure to equalize. Instantaneous closure is not acceptable.

- M. Factory assemble damper, actuator, sleeve, and accessories and furnish as a single unit conforming to UL 555 and UL 555S.
- N. Performance Data:
 - 1. Elevated Temperature Qualified: Damper and actuator assembly qualified in accordance with UL 555S to elevated temperature of 350 degrees F.
 - 2. Leakage Class I, when applied in systems with maximum pressure of 4 inches w.g.

2.06 ACTUATORS

- A. Actuator motor shall be silent microprocessor controlled providing electronic cutoff.
- B. Motor shall direct coupled and incapable of burning out if stalled before full rotation is reached.
- C. Housing, gears and toothed cold-weld clamp shall be steel.
- D. Operation time: 15 seconds at 32 to 350 degrees F.

2.07 ACCESSORIES FOR DAMPERS

- A. Interlock switch: Electrically and mechanically lock damper in closed position when duct temperatures exceed [165 degrees F] [212 degrees F] and still allow appropriate authority to override interlock switch and operate damper as may be required for smoke management functions. Allow damper to remain operable while temperature is below 350 degrees F. Switch shall comply with NFPA 92A and be UL classified.
- B. Interface with smoke detectors, building fire alarm systems or remote indicating and control stations.
- C. High Limit Temperature Sensor:
 - 1. Returns damper to fire protection mode when temperatures reach operational limit of damper and actuator assembly of 350 degrees F.
 - 2. Conform to NFPA 92A.
 - 3. Replaces controlled closure devices on standard dampers.
- D. Blade Position Indicator Switches: Two position indicator switches linked directly to damper blade to remotely indicate damper blade position.
- E. Picture Frame Mounting Angles:
 - 1. One-piece, roll formed retaining angles, 1-1/2 by 1-1/2 inches. Requires factory sleeve.
 - 2. Factory matched and shipped on individual damper with factory prepunched screw holes.
- F. Steel Mullions: For dampers in oversized masonry wall openings.
- G. Provide breakaway connection: Drivemate, Ductmate or equal.

2.08 BALANCING DAMPERS – SINGLE BLADE

- A. Provide volume dampers as specified or shown on the Drawings for proper balancing and distribution of air, in the various branches of the ductwork for use in testing and balancing the

system. Dampers shall be installed separate and independent from the damper specified to be set behind supply, return and exhaust air grilles. Provide single blade dampers in ducts 24 inches in width or less, or 12 inches in height or less. Provide multiple blade dampers for all other duct sizes. Coordinate with the air balancing contractor and provide additional dampers required for proper air balance.

- B. Provide single blade and quadrant type volume dampers of minimum 20-gauge round or 22-gauge rectangular galvanized steel construction, pivoted to turn easily. Provide operating handles and Ventline 560 or equal locking devices mounted on outside of the duct in an accessible location. Blade shall have 4 full length brakes for increased stiffness and rigidity.
- C. Damper component penetration shall be closed and sealed consistent with the specified duct sealing class. End bearings are required for 3-inch water gauge class.

2.09 BALANCING DAMPERS – MULTIPLE BLADES

- A. Manual dampers shall have a minimum 16-gauge galvanized steel channel frame with mounting flanges and axles set in molded polycarbonate or oil impregnated bronze bearings. Axles shall be minimum of ½ inch in diameter and shall be interlocked with blades to positively eliminated slippage.
- B. Blades shall be minimum of 16-gauge galvanized steel. Manual dampers shall have a minimum of four breaks running the entire length of the damper to assure rigidity and tight close off. Blades shall be on centers no greater than 9 inches and no blade shall exceed 48 inches in length. All blades shall be interconnected to act in unison for opposed blade operation.
- C. When installed, damper frame shall be gasketed or caulked to eliminate leakage between duct or plenum and damper frame. Head and sill shall have stops. Damper shafts shall be marked to indicate blade position.
- D. Dampers shall be provided with Ventline 560 or approved equal, locking quadrants of sufficient size and design to securely hold the damper sections and blade linkage hardware.

2.10 BACKDRAFT DAMPERS – COUNTERBALANCED TYPE

- A. Provide counterbalanced backdraft dampers as specified and where indicated on the Drawings. Each damper shall be sized as indicated on the Drawings, and shall be suitable for installation in the mounting arrangement shown.
- B. Backdraft damper shall be the heavy duty pressure relief counter-balanced shutter type similar to Ruskin type CBD4, or approved equal.
- C. Damper frame shall be minimum 16-gauge galvanized steel or 16-gauge aluminum. Damper frame shall be of channel construction for ductwork mounting or have a front flange when installed in a wall.
- D. Damper blades shall be minimum 16-gauge galvanized steel or 16-gauge aluminum. Provide individual adjustable counterweights on each blade. The damper shall be capable of maintaining static pressures of 0.05 to 0.20 inches water gauge. Furnish tie bars constructed of minimum 16-gauge galvanized steel or 16-gauge aluminum on damper sections over 24 inches wide. After damper has been installed, counterweights shall be adjusted to balance the system static pressure as directed by the test and balancing contractor.
- E. Damper blades shall have polyurethane foam, neoprene, or vinyl gaskets glued, riveted or rolled into blade edges.
- F. Damper bearings shall be molded polycarbonate, bronze oilite, nylon, or cocoloy.

- G. Furnish counter-balanced backdraft dampers with No. 1½ mesh aluminum bird screen for rear mounting where counter-balanced backdraft dampers are mounted in outside walls.

2.11 HEAVY DUTY BACKDRAFT DAMPERS – COUNTERBALANCED TYPE

- A. Provide heavy duty counterbalanced backdraft dampers as specified and where indicated on the Drawings. Each damper shall be sized as indicated on the Drawings, and shall be suitable for installation in the mounting arrangement shown.
- B. Heavy duty backdraft damper shall be the heavy duty counter-balanced shutter type similar to Ruskin type CBS92, or approved equal.
- C. Damper frame shall be minimum 0.125-inch thick aluminum. Damper frame shall be of channel construction with bolted flanges for ductwork mounting in fan discharge applications.
- D. Damper blades shall be airfoil shaped minimum 16-gauge extruded aluminum. The damper shall be capable of operating at 4,000 feet per minute velocity and a maximum system pressure of 5 inches water gauge on a 60-inch wide damper. After damper has been installed, counterweights shall be adjusted to balance the system static pressure as directed by the test and balancing contractor.
- E. Damper blades shall have silicone rubber seals mechanically locked into blade edges. Provide vinyl jamb seals.
- F. Damper bearings shall be stainless steel sleeve bearing in cast housing bolted to the frame. Axles shall be ¾ inch stainless steel.

2.12 BACKDRAFT DAMPERS

- A. Furnish and install backdraft dampers as specified and where indicated on the Drawings. Each damper shall be sized as indicated on the Drawings and shall be suitable for installation in the mounting arrangement shown. Backdraft dampers mounted in roof curbs shall be secured to galvanized steel support angles fastened to the curb.
- B. Backdraft dampers shall be heavy duty relief shutter type suitable for wall and duct mounting or installation at a centrifugal fan discharge. Backdraft dampers shall be similar to Ruskin Type BD2-A1 for face velocities to 1500 feet per minute and Ruskin Type BD2-A2 for face velocities to 2500 feet per minute or approved equal.
- C. Damper frame shall be constructed of minimum 0.090-inch thick aluminum or minimum 18 gauge galvanized steel. Damper frame shall be of channel construction when installed in ductwork or have a front flange when installed in a wall.
- D. Damper blades shall be constructed of minimum 0.025-inch thick extruded aluminum suitable for face velocities up to 1500 feet per minute and minimum 0.05-inch thick extruded aluminum for face velocities to 2500 feet per minute. Damper blades shall have neoprene or vinyl gaskets riveted or rolled into the blade edge. Each backdraft damper section shall be furnished with tie bars constructed of minimum 16-gauge aluminum. Furnish two tie bars on damper sections over 40 inches wide.
- E. Damper bearings shall be molded polycarbonate, bronze oilite, nylon, or cyclopol.
- F. Furnish backdraft dampers with 1.5-inch by 1.5-inch 22-gauge wire mesh aluminum bird screen for rear mounting where backdraft dampers are mounted in outside walls.
- G. Damper leakage shall not exceed 12 cubic feet per minute per square foot of damper face area at 0.5 inches water gauge differential pressure.

2.13 REMOTE CABLE CONTROLS FOR DAMPERS

- A. Manufacturer shall supply all necessary hardware for simple installation of remote cable controls system including the Bowden aluminum angle bracket and the Bowden control hub to accommodate the cable control system mounted on the damper.
- B. Cable control system shall consist of Bowden cable 0.054-inch stainless steel control wire encapsulated in 1/16-inch flexible galvanized spiral wire sheath to insure positive operation for up to 50 feet (can be reduced if there are multiple turns or bends).
- C. Control kit shall be designed for use with internally or externally controlled round or rectangular dampers and shall consist of 14 gauge steel rack and pinion gear drive to convert rotary motion to push-pull motion. Control shaft shall be D-style flattened with 265-degree rotation providing graduations for positive locking control and linear travel.
- D. Control mounting options include ceiling framework, behind grilles, on or inside plenum slot diffusers and other various types of diffusers or through ceiling via 1-inch diameter inconspicuous access port. Twisting type cables are not acceptable.
- E. Manual quadrant shall be commercial quality, locking type for 3/8-inch square shaft. Provide extended base for externally insulated ductwork.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Install dampers square and free from twist or racking with blades running horizontally.
- B. Do not compress or stretch damper frame into duct or opening.
- C. Handle and lift damper using sleeve or frame. Do not lift damper using blades, accessories, actuator, or jackshaft. Handle dampers in accordance with manufacturer's instructions. Protect materials and finishes during handling and installation to prevent damage.
- D. Provide conveniently located access doors, of ample size for resetting the dampers. Duct mounted grilles, registers or diffusers can be used for access as long as such access is readily available as determined by the Architect, Owner or Authority Having Jurisdiction.
- E. Install automatic control dampers of louver pattern including smoke dampers and fire/smoke dampers, as indicated on the Drawings or as specified in intake ducts and/or plenums, discharge ducts and plenums from fans, etc. These dampers shall be provided by the automatic control contractor.
- F. Provide a 16-gauge elevated platform at least 1/8-inch higher than the insulation thickness for all balancing dampers installed in externally insulated ductwork. Damper shaft bearing shall be mounted on elevated platform.
- G. Install remote operators for balancing dampers where damper is located above drywall, plaster or other inaccessible ceiling construction where access panels are not provided.
- H. Fire damper operation shall be tested after the installation is complete. Static fire dampers shall be tested with the system fans not operating. Dynamic fire dampers shall be tested with system fans operating at their maximum static pressure ratings. A written certificate shall be issued by the Contractor to the Owner stating:
 - 1. Damper identification
 - 2. Damper location

3. Date tested
 4. Names and signatures of witnesses and testing personnel
-
- I. Provide a copy of certification to system balancing agent for inclusion in balancing report.
 - J. Size and quantity of dynamic fire damper shall be based on the UL listing of the damper manufacturer. Provide intermediate mullions and split duct connections as required.
 - K. Provide ribbon at each manual damper handle.
 - L. Dynamic dampers shall be used in the following systems:
 1. []

END OF SECTION

SECTION 23 33 19

ACOUSTICS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
 - 1. Sound attenuators
 - 2. Sound lining
 - 3. Vane axial fan diffuser/silencer

1.02 RELATED DOCUMENTS

- A. Section 23 05 01 - Mechanical General Provisions
- B. Section 23 05 48 - Vibration Isolation and Seismic Restraints
- C. Section 23 05 93 - Mechanical Systems Balancing
- D. Section 23 07 00 - Insulation
- E. Section 23 31 00 - Ductwork
- F. Section 23 37 00 - Air Outlets and Inlets

1.03 SUBMITTALS

- A. Shop Drawings:
 - 1. Sound attenuators, vane axial fan diffuser/silencer.
 - 2. Sound lining.
 - 3. Certification that sound lining meets erosion test method described in U.L. Publication No. 181 Erosion Test Method.
 - 4. Non-hardening caulking.
 - 5. Submit certified test data from approved laboratory for pressure drop and insertion loss ratings. ASTM – American Society for Testing and Materials Standard E477; Standard C423 – Method for Measuring Sound.
 - a. For square or rectangular attenuators: test results for a 24-inch x 24-inch cross-section attenuator.
 - b. Certification data for pressure drop and net insertion loss: based on tests of same attenuator.
 - c. Attenuators and tests: subject to inspection upon request.
 - d. Record acoustic ratings, including dynamic insertion loss and self-noise power levels with an airflow of 2000 fpm face velocity.
 - e. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or 6-inch water gauge static pressure, whichever is greater.
- B. Noise generated by mechanical equipment shall be a guaranteed maximum when operating at the specified conditions.

1.04 REFERENCE STANDARDS

- A. Published specifications standards, tests or recommended methods of trade, industry or

governmental organizations apply to work in this section where cited below:

1. ADC – Air Diffusion Council – ACD 1062R-4: Certification Rating and Test Manual
2. AMCA – Air Movement and Control Association Standard 300 – Determination of Fan Sound Power Levels
3. ANSI – American National Standards Institute Standard S1.13 – Precision Methods for the Determination of Sound Power Levels of Broadband Noise Sources in Reverberant Rooms
4. ARI – American Refrigeration Institute Standards:
 - a. Standard 575 – Measurement of Sound in Equipment Rooms
 - b. Standard 885 – Sound Transmission Losses
 - c. Standard 443 – Standard for Sound Rating of Fan Coil Air Conditioners
5. ARI/ADC Standard 880 – Industry Standard for Air Terminals
6. ASHRAE – American Society of Heating Refrigeration and Air Conditioning Engineers Standard 36 – Determination of Ventilating Equipment Sound Power
7. ASTM – American Society for Testing and Materials:
 - a. Standard E477 – Standard Test for Measuring Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers. During the test, there shall be air flowing through the tested sound traps at a velocity of 1,000 feet per second plus or minus 5 percent.
 - b. Standard C423 – Method for Measuring Sound Absorption
 - c. Standard E90 – Method for Measuring Sound Transmission Loss
 - d. Standard E413 – Determination of Sound Transmission Class
8. ISO – International Standards Organization 5135 and 3741 – Acoustics
9. Refer to Section 23 37 00: Air Inlets and Outlet for additional reference standards.

1.05 QUALITY ASSURANCE

A. Acoustical Criteria:

1. Noise levels, generated by equipment and ductwork shall be attenuated to permit attainment of sound pressure levels in all 8 octave bands in occupied spaces that conform to the following Noise Criteria (NC) curves:
 - a. Lobbies, corridors, toilets, spaces within 10 feet of duct penetrations through shaft and equipment room walls and floors of equipment rooms: NC-40.
 - b. Laboratories:
 - (1) With fume hoods: NC-50
 - (2) Without fume hoods: NC-40
 - c. Conference Rooms:
 - (1) Small: NC-35
 - (2) Large: NC-30
 - d. Executive Offices: NC-30
 - e. Storage Spaces: NC-50
 - f. All other spaces: NC-35
2. In addition to complying with the standard full octave band sound pressure levels based on maximum NC design requirements, acoustical performance of mechanical equipment when operating under design conditions shall not create any objectionable pure tones. A pure-tone is defined as a peak sound pressure level which, when measured in 1/3 octave band frequencies, is higher by more than 5

- decibels than adjacent 1/3 octave band frequencies.
3. Comply with specified NC levels for radiated noise from terminal and pressure regulating devices and/or duct breakout noise by having full octave band sound pressure levels of at least two contiguous frequencies tangent to the NC spectrum. A single frequency controlled NC environment is considered obtrusive and unacceptable.

B. Mechanical Performance:

1. Air distribution system equipment; terminal device noise:
 - a. Maximum permissible sound-power levels in octave bands of airborne transmissions through the combination of grilles, registers, diffusers, and terminal units, or related pressure reducing devices, when operated in installed condition with 3-feet of unlined duct shall be as follows:

| Octave Band Frequency (Hertz) | Octave Band Number | Maximum PWL in Decibels Referred to 10 ⁻¹² Watts for space being served | | | | |
|-------------------------------|--------------------|--|-------|-------|-------|-------|
| | | NC-30 | NC-35 | NC-40 | NC-45 | NC-50 |
| 63 | 1 | 60 | 65 | 70 | 68 | 70 |
| 125 | 2 | 58 | 60 | 65 | 63 | 66 |
| 250 | 3 | 55 | 60 | 65 | 58 | 62 |
| 500 | 4 | 53 | 60 | 60 | 56 | 61 |
| 1000 | 5 | 50 | 60 | 60 | 53 | 58 |
| 2000 | 6 | 50 | 60 | 60 | 52 | 57 |
| 4000 | 7 | 40 | 50 | 60 | 51 | 56 |
| 8000 | 8 | 37 | 42 | 47 | 52 | 57 |

2. Pressure reducing terminal devices above ceiling; radiated noise:
 - a. Maximum permissible radiated sound-power levels in octave bands when operated in installed condition over occupied spaces, is as follows:

| Octave Band Frequency (Hertz) | Octave Band Number | Maximum PWL in Decibels Referred to 10 ⁻¹² Watts | | | |
|-------------------------------|--------------------|---|-------|-------|-------|
| | | NC-35 | NC-40 | NC-45 | NC-50 |
| 63 | 1 | 72 | 76 | 79 | 82 |
| 125 | 2 | 70 | 74 | 77 | 80 |
| 250 | 3 | 61 | 65 | 68 | 71 |
| 500 | 4 | 60 | 64 | 68 | 72 |
| 1000 | 5 | 57 | 62 | 68 | 72 |
| 2000 | 6 | 56 | 60 | 65 | 70 |
| 4000 | 7 | 66 | 70 | 75 | 80 |
| 8000 | 8 | 65 | 70 | 75 | 80 |

3. Provide sound lining in accordance with UL 181.
4. Provide all materials in accordance with NFPA, UL and state and local codes.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Sound Attenuators and Vane Axial Fan Diffuser/Silencers: Industrial Acoustics, Koppers, Vibro-Acoustics

- B. Sound Linings: Certainteed ToughGuard, Schuller, Owens-Corning Fiberglas
- C. Circular Duct Lining: Casco Circliner, Schuller Spiracoustic
- D. Factory Pre-Fabricated Double Wall Lined Duct: United McGill, Sheet Metal Products
- E. Fire Retardant Adhesive and Sealer: Foster 85-20 or approved equal.
- F. Non-hardening caulking shall be guaranteed to be permanently elastic. Tremco Polybutene or approved equal.

2.02 MATERIALS

- A. Factory Prefabricated Sound Attenuators:
 - 1. Fire Performance: Adhesives, sealants, packing materials and necessary accessory materials shall have fire ratings not exceeding 25 for flame-spread index and 50 for smoke-developed index when tested according to ASTM E 84.
 - 2. Rectangular Units: Fabricate casings with a minimum of 22-gauge solid galvanized sheet metal for outer casing and 26-gauge, ASTM A 653/A 653M, G90, perforated galvanized sheet metal for inner casing.
 - 3. Round Units:
 - a. Outer Casings:
 - (1) ASTM A 653/A 653M, G90, galvanized sheet steel.
 - (2) Up to 24 inches in diameter: 22-gauge.
 - (3) 26 through 60 inches in diameter: 18-gauge.
 - (4) Casings fabricated of spiral lock-seam duct may be one gauge lighter than that indicated.
 - b. Interior Casing, Partitions and Baffles:
 - (1) ASTM A 653/A 653M, [G90] [G60], galvanized sheet steel.
 - (2) Minimum 26-gauge and designed to minimize aerodynamic losses.
 - 4. Sheet Metal Perforations: 1/8-inch diameter for inner casing and baffle sheet metal.
 - 5. Filler Material: Inert and vermin-proof fibrous material, packed under not less than 5 percent compression, mechanically fastened to the steel panels and protected by an impervious membrane. Filler material shall be totally encapsulated and sealed with a polymer film of an approximate thickness of 1.5 mils. The encapsulated fill material shall be separated from the perforated baffles by means of a non-combustible, erosion resistant acoustic standoff.
 - 6. Rectangular casing seams shall be located in the corners of the attenuator shell to provide strength and rigidity. Interior partitions shall be fabricated from single piece, perforated sheets with die-formed entrance and exit shapes.
 - 7. Attachment of the interior partitions to the casing shall be by means of an interlocking track assembly. Tracks shall be solid galvanized steel and shall be welded to the outer casing.
 - 8. The track assembly shall stiffen the exterior casing, provide a reinforced attachment detail for the interior partitions, and shall maintain a uniform airspace width along the length of the attenuator.
 - 9. Where noted on the schedule, no sound absorption material of any kind shall be used. Attenuate air-transmitted noise solely by virtue of controlled impedance membranes and tuned resonators.
 - 10. Attenuators subjected to corrosive environments shall be constructed of Type 316 stainless steel.
 - 11. Attenuators shall form rigid units that do not pulsate, vibrate, rattle, or otherwise react to system pressure variations.

- a. Do not use nuts, bolts or sheet metal screws for unit assemblies.
 - b. Lock form and seal or continuously weld joints.
 - c. Suspended Units: Factory installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
12. Minimum net insertion loss ratings as determined by duct-to-reverberant room test method at design airflow shall be as follows:

| Octave Band Number | Octave Band Frequency (Hertz) | Dynamic Net Insertion Loss in Decibels | | | | | |
|--------------------|-------------------------------|--|----|----|----|----|----|
| | | Sound Trap Types/Lengths | | | | | |
| | | 3L | 5L | 7L | 3S | 5S | 7S |
| 63 | 1 | 5 | 7 | 13 | 12 | 18 | 20 |
| 125 | 2 | 9 | 13 | 18 | 24 | 16 | 35 |
| 250 | 3 | 14 | 21 | 28 | 28 | 40 | 45 |
| 500 | 4 | 23 | 29 | 40 | 35 | 45 | 50 |
| 1000 | 5 | 24 | 39 | 47 | 35 | 46 | 48 |
| 2000 | 6 | 56 | - | - | - | - | - |
| 4000 | 7 | 66 | - | - | - | - | - |
| 8000 | 8 | 65 | - | - | - | - | - |

13. Maximum Self-Generated Noise:

- a. At 2000 feet per minute face velocity and 4 square feet face area:

| Octave Band Number | Octave Band Frequency (Hertz) | Sound Power Level in Decibels re 10^{-12} Watts L Series Sound Trap Type |
|--------------------|-------------------------------|--|
| 2 | 125 | 51 |
| 3 | 250 | 51 |
| 4 | 500 | 49 |
| 5 | 1000 | 47 |
| 6 | 2000 | 50 |

- b. At 1000 feet per minute face velocity and 4 square feet face area:

| Octave Band Number | Octave Band Frequency (Hertz) | Sound Power Level in Decibels re 10^{-12} Watts S Series Sound Trap Type |
|--------------------|-------------------------------|--|
| 2 | 125 | 49 |
| 3 | 250 | 49 |
| 4 | 500 | 47 |
| 5 | 1000 | 46 |
| 6 | 2000 | 49 |

| Octave Band Number | Octave Band Frequency (Hertz) | Dynamic Net Insertion Loss in Decibels | | | | | |
|--------------------|-------------------------------|--|----|----|----|----|----|
| | | Sound Trap Types | | | | | |
| | | 3L | 5L | 7L | 3S | 5S | 7S |
| 2 | 125 | 5 | 7 | 13 | 12 | 18 | 20 |
| 3 | 250 | 9 | 13 | 18 | 24 | 16 | 35 |
| 4 | 500 | 14 | 21 | 28 | 28 | 40 | 45 |
| 5 | 1000 | 23 | 29 | 40 | 35 | 45 | 50 |

| Octave Band Number | Octave Band Frequency (Hertz) | Dynamic Net Insertion Loss in Decibels | | | | | |
|--------------------|-------------------------------|--|----|----|----|----|----|
| | | Sound Trap Types | | | | | |
| | | 3L | 5L | 7L | 3S | 5S | 7S |
| 6 | 2000 | 24 | 39 | 47 | 35 | 46 | 48 |

B. Vaneaxial Fan Diffuser/Silencer:

- Construct diffuser/silencers of inorganic, noncombustible materials meeting Code requirements and flame spread rating of 25 and smoke developed of 50.
- The diffuser/silencer shall be specifically designed for mounting at the inlet and outlet of manufacturer's vaneaxial fan. Diffuser/silencer performance shall be specifically rated with the fan manufacturer and fan size selected. Provide flow direction indicator labels on the exterior casing.
- Diffuser/silencers shall include an internal core of consistent diameter along the entire length in direction of airflow. The core diameter shall be selected based on the adjacent hub diameter or, in the case of C-frame mounted motors, the motor frame size for the respective fan system on which the diffuser silencer is installed. The core shall be constructed from lock formed quality type G-90 galvanized perforated steel in the same gauge as the internal diffuser core. The core shall be supported by a minimum of three welded radial attachment brackets installed on 120 degree angles to each other to provide uniform support.
- Provide 4-inch long, 12-gauge, sleeved end connections as standard. When noted, rolled angle flanges shall be welded to the sleeve by the manufacturer. For units where the minimum diffuser core diameter is 36 inches or greater, an additional support rod shall be welded between the radial bracket and the sleeve to prevent a twist from being exerted on the internal core by the airflow of the fan.
- Diffuser/silencers shall function as pressure regain devices to minimize system pressure losses at the fan. Fan selections are based on the regain performance of the diffuser/silencer configurations specified.
- The diffuser/silencer shall meet the following requirements for dynamic insertion loss (forward flow):

| Diffuser Outlet Diameter (inches) | Dynamic Insertion Loss in Decibels | | | | | | | |
|-----------------------------------|---------------------------------------|-----|-----|-----|------|------|------|------|
| | Octave Band Center Frequency in Hertz | | | | | | | |
| | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| 30 | - | 2 | 12 | 20 | 26 | 22 | 16 | 12 |
| 32 | - | 4 | 14 | 20 | 24 | 20 | 15 | 12 |
| 34 | 1 | 5 | 15 | 20 | 22 | 18 | 14 | 12 |
| 36 | 1 | 7 | 16 | 19 | 20 | 17 | 13 | 11 |
| 40 | 1 | 8 | 16 | 19 | 19 | 14 | 10 | 9 |
| 42 | 2 | 9 | 16 | 18 | 19 | 14 | 10 | 10 |
| 46 | 2 | 9 | 16 | 18 | 19 | 14 | 10 | 10 |
| 48 | 2 | 9 | 15 | 18 | 18 | 15 | 11 | 10 |
| 52 | 3 | 10 | 16 | 18 | 16 | 13 | 11 | 10 |
| 56 | 3 | 10 | 16 | 18 | 16 | 13 | 11 | 10 |
| 60 | 3 | 11 | 18 | 19 | 17 | 13 | 12 | 10 |
| 68 | 3 | 11 | 17 | 19 | 17 | 12 | 12 | 10 |
| 74 | 4 | 12 | 18 | 20 | 16 | 12 | 11 | 10 |
| 82 | 4 | 12 | 18 | 20 | 16 | 12 | 11 | 10 |
| 90 | 4 | 12 | 18 | 18 | 15 | 10 | 10 | 10 |
| 98 | 4 | 12 | 18 | 17 | 15 | 9 | 10 | 10 |
| 104 | 4 | 12 | 18 | 16 | 14 | 8 | 9 | 10 |

C. Duct Lining:

1. Low-pressure fiberglass duct liner downstream of terminal units shall be finished with an acrylic polymer facing stenciled NFPA 90.
2. Medium pressure duct liner shall be finished with perforated 24-gauge galvanized sheet metal, 28 percent minimum open area or foil facing equal to Owens Corning 703 FRK.
3. Thickness:
 - a. In ductwork: minimum 1 inch matte faced unless otherwise noted on drawings or specification.
 - b. In plenums and in supply, return or exhaust duct downstream of local floor equipment rooms: minimum 2 inches, 3 pound per cubic foot density, semi-rigid.
 - c. For sound lining where used in lieu of external thermal insulation minimum thickness shall conform to requirements as specified in Section 23 07 00: Insulation.
 - d. Linear Diffuser Supply Plenums: Minimum ½ inch, 1½ pound per cubic foot density.
4. Minimum density ducts: 1½ pounds per cubic foot.
5. Minimum density, plenums: 3 pounds per cubic foot.
6. Flamespread shall be maximum 25; fuel contributed and smoke developed shall be maximum 50.
7. Suitable for duct velocity of 4000 feet per minute. Meet erosion test method described in U.L. Publication No. 181.
8. Dynamic Loss Coefficient: Maximum 1.2.
9. K Factor: Maximum 0.25 Btu/inch-hour – degree Fahrenheit – square foot.
10. Minimum sound-absorption coefficients (ASTM C423 Mounting #6 or F-25) for sound-absorbing duct lining material when tested while mounted to 24-gauge sheet metal.

| Lining Thickness (inches) / Density (pounds per cubic foot) | Octave Band Center Frequency (Hertz) | | | | | |
|--|--------------------------------------|-----|-----|------|------|------|
| | 125 | 250 | 500 | 1000 | 2000 | 4000 |
| 1-inch / 1.5 to 3.0 pound | .05 | .25 | .50 | .70 | .85 | .85 |
| 1.5-inch / 1.5 to 3.0 pound | .20 | .40 | .70 | .90 | .90 | .85 |
| 2-inch / 1.5 to 3.0 pound | .25 | .50 | .80 | .90 | .90 | .90 |

11. Where acoustically lined circular or oval duct is required, lining shall be positively retained in place.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. In order to obtain satisfactory acoustical performance of the mechanical systems, complete the following:
 1. Duct connections at inlet to the terminals
 2. Air-balancing
 3. Avoid excessive dampering right at the terminals
- B. Duct and duct supports shall not contact ceiling framing, ceiling supports, piping or pipe supports

C. Sound Attenuators:

1. Install in accordance with manufacturer's recommendations to obtain published and specified performance.
2. Provide 22-gauge galvanized steel wire mesh screen on all sound attenuator inlets or outlets not connected to ductwork or fans.
3. Provide watertight aluminum jacket on all sound attenuators installed outside. Installation shall comply with SMACNA standards for outdoor installations.

D. Sound Linings:

1. Adhere with 6-inch wide strips of adhesive at 12-inch centers at all joints in lining.
2. In addition, secure with grip nail standard stamp on or weld pins and 2-inch diameter integral or press-on head washers on maximum 16 inch centers and in compliance with SMACNA standards.
3. Coat all edges with sealer.
4. Provide continuous sheet metal edge protection nosings at entering and leaving edges of lined duct sections and all joints.
5. Dimensions of lined ductwork are clear inside dimensions after lining has been installed.
6. Extent of ductwork sound linings.

a. Heating, Ventilating and Air-Conditioning Systems:

- (1) Supply: Ductwork within mechanical equipment rooms and not less than 25 feet downstream of fan room and mechanical equipment room walls and floor slabs.
- (2) Exhaust, Relief and Return: Ductwork in fan rooms and mechanical equipment rooms but not less than 25 feet from fan or 15 feet from room walls.

b. Outside air supply systems a minimum distance of 25 feet downstream of fan. Stop lining 10 feet from outside air intake.

c. Ductwork installed outside building: All exposed ductwork a minimum of 10 feet downstream of wall, roof or floor penetrations.

d. Ventilation systems: As indicated on Drawings.

e. Exhaust systems: As indicated on Drawings.

f. Ductwork downstream of fan coil units, heat pumps, AC units or terminal units: Minimum 10 feet. Branch takeoffs to diffusers are not allowed in this 10-foot lined section.

g. Ductwork upstream of ducted fan coils, heat pumps, AC units: 4 feet minimum.

h. Minimum lengths specified or shown. Provide additional acoustical treatment as required to meet maximum permissible sound-power levels scheduled for equipment.

7. Sound-lined plenums: As specified and indicated on Drawings.

8. All transfer and jumper ducts.

9. All linear diffuser supply plenums.

E. Soundproofing of Construction:

1. Required for packing between ductwork and the following construction:

a. Fan room and mechanical equipment room walls.

b. Floors, except in shafts.

c. Sound barrier ceilings.

d. Sound rated walls: Any interior wall or partition with internal insulation. Refer to Architectural drawings.

2. Soundproofing:
 - a. Fill openings with fiber glass blanket or board for full depth of penetration.
 - b. Caulk each side of opening with non-hardening, non-aging caulking compound. Schuller "Duxseal" or approved equal.
 3. Soundproofing may be deleted when firestopping material is provided.
- F. Ductwall External Soundproofing:
1. Extent:
 - a. Vane axial fans including their inlet and discharge transitions and sound attenuators.
 - b. Where indicated on Drawings.
 2. Soundproofing Material:
 - a. Fiber Glass Board:
 - (1) Density: 6 pounds per cubic foot.
 - (2) Thickness: ½ inch greater than height of ductwork angles, but 2 inches minimum.
 - b. External Jacket:
 - (1) Lead sheet overlapped 2 inches and secured with tape.
 - (2) Weight: 1 pound per square foot.
 - (3) Thickness: 1/64 inch.
- G. Sound Attenuators Tests:
1. After installation, measure total system pressure before and after attenuators.
 2. If pressure loss exceeds maximum static pressure scheduled on drawings, replace attenuators and/or modify entrance and/or discharge aerodynamic flow to obtain specified performance.
- H. Do not install flexible duct through walls or ceilings.
- I. Acoustical Testing: The contractor shall cooperate with the test and balance contractor to allow acoustical testing to be executed during the testing and balancing.

END OF SECTION

SECTION 23 34 00

FANS

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this section shall include, but is not limited to the following:

1. Centrifugal Fans:
 - a. Scroll
 - b. Cabinet
 - c. Tubular Centrifugal
 - d. Plug (Unhoused Centrifugal)
2. Axial Fans:
 - a. Propeller
 - b. Vaneaxial – Fixed Blade
 - ~~c. Vaneaxial – Adjustable Blade~~
 - ~~d. Mixed Flow~~
3. Roof Exhaust Fans:
 - a. Backdraft dampers for vaneaxial fans

1.02 SUBMITTALS

- A. Submit construction details, gauges of fan wheels and housing components and certified dimensioned drawings.
- B. Submit manufacturer's latest published data for weights, materials, accessories and installation details.
- C. Submit full technical rating data based on tests in accordance with current AMCA standards and in an AMCA approved laboratory. Fan curves shall indicate the relationship of airflow to static or total pressure for various fan speeds. Brake horsepower, recommended selection range, and limits of operation shall also be indicated on the curves. Indicate operating point on the fan curves at design air quantity and indicate the manufacturer's recommended drive loss factor for the specific application. Tabular fan performance data is not acceptable.
 1. Include manufacturer's certified fan volume-pressure performance curves, from shutoff to free delivery. Consider drive efficiency in motor selection according to manufacturer's published recommendation or according to AMCA Publication 203, Appendix L.
 2. Include certified sound power ratings based on tests performed in accordance with AMCA Standard 300. Correct all ratings and curves for altitude and temperature where applicable.
- D. Motor construction and efficiencies.
- E. Bearing life calculations based on maximum design speed for the class of each fan scheduled on the drawing.
- F. Fan shaft critical speed at scheduled performance.

- G. For variable air volume application, include data that indicates the effect of capacity control devices, such as inlet vanes, on performance.

1.03 QUALITY ASSURANCE

- A. For each fan, provide a multispeed fan performance curve with multiple horsepowers on a single sheet. Computer generated single speed fan curves are not acceptable.
- B. Provide a full two-year parts and labor warrantee for all fan-mounted control air compressors.

1.04 REFERENCE STANDARDS

- A. Construct all fans, except vaneaxial adjustable blade, to comply with the requirements of the latest editions of the Air Moving and Conditioning Association (AMCA) Standards and Bulletins. Certify these fans by AMCA for performance and sound ratings and provide the AMCA Performance and Construction Seal for Air and Sound.
 - 1. AMCA 203 - AMCA Fan Application Manual - Troubleshooting
 - 2. AMCA 210 - Laboratory Method of Testing Fans for Rating
 - 3. AMCA 300 - Reverberant Room Method for Sound Testing of Fans
 - 4. NFPA 90A - Standard for the Installation of Air Conditioning and Ventilating Systems
 - 5. ANSI/AFBMA 9 - Load Ratings and Fatigue Life for Ball Bearings
 - 6. ANSI/AFBMA 11 - Load Ratings and Fatigue Life for Roller Bearings
- B. NFPA 96: Standard for the Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Centrifugal Fans: Twin City, Chicago, Buffalo, Greenheck, Loren Cook
- B. Propeller Fans: Twin City, Greenheck, Bayley, Woods, Loren Cook
- C. Axial Fans Fixed Blade: Twin City, Chicago, Greenheck, Loren Cook
- D. Axial Fans Adjustable Blade: Twin City, Woods, Joy, Loren Cook
- E. Roof Exhaust Fans: Greenheck, Penn, Loren Cook, Greenheck
- F. Mixed Flow Fans: Woods, Loren Cook, or approved equal
- G. Swing-out Centrifugal Fans: Twin City, Chicago, Loren Cook
- H. Clamshell Axial Fans: Twin City, Chicago, Loren Cook

2.02 GENERAL – ALL FANS

- A. Unless noted otherwise, provide discharge direction and drive arrangement to suit space conditions and conform as closely as possible to the layouts shown on the Drawings. Maintain clearance for service and access to all components.
- B. Provide factory-fabricated, -assembled, -tested, and -finished fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and support structure. Fans shall be quiet operating and non-overloading over the entire range of operation.

- C. Provide fan motors in accordance with Section 23 05 13 - Electric Motors. Size motor to drive its respective fan when the fan is operating at a speed 5 percent in excess of that required to meet the scheduled fan performance. Do not select motors within the service factor for this range.
- D. Statically and dynamically balance fan wheels/impellers at the factory and certify balance. Design all vertically mounted fans to withstand the vertical thrust loads.
- E. Provide precision self-aligning bearings designed to prevent leakage of oil or grease. Provide cups, oil chambers, Zerk or Alemite lubrication fittings in accessible locations for ease of lubrication. Provide heavy duty split pillow block bearings with tapered, double-row spherical roller assemblies. Provide bearings with AFBMA L₁₀ service life in excess of 200,000 hours at maximum published fan operating conditions for the AMCA construction class required unless noted or specified otherwise.
- F. Provide copper lubrication leads, for lubrication of internal motors and bearings, extending to a capped termination point external to the fan casing or air handling unit.
- G. Extend wire leads on fans driven by direct motor drive from the motor junction box in airtight rigid walled conduit, to a junction box mounted external to the fan casing.
- H. On fans driven by belt drive provide standard "V-groove" type oil resistant, non-sparking, and non-static belts with cast iron or steel sheaves suitable for the service intended. Fan sheaves shall be non-adjustable type with removable machined bushings. Provide adjustable pitch type motor sheaves with double locking feature, to 10 percent above and below the rated fan speed. Dynamically balance sheaves with over three grooves. Provide at least two belts and sheaves each capable of carrying the entire load with one belt broken.
- I. Provide pre-formed expanded metal and sheet metal belt guards at the fan and motor shafts, for all exposed sheaves and belts. Guard shall comply with OSHA and SMACNA requirements; 0.1046-inch thick, 3/4-inch diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short-circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
- J. For motors in the airstream, provide TEFC type motors, unless other types are required as specified in Section 23 05 13 - Electric Motors.
- K. Provide solid hot rolled steel drive shafts, accurately turned and polished to a close tolerance where in contact with bearings. Secure fan wheels/impellers to the drive shaft by a key and keyway assembly. Shafts shall be sized for first critical speed and at least 1.43 times maximum speed for AMCA fan class.
- L. Manufacture fans of materials and paint finishes suitable for the service intended.
- M. Construct wheels/impellers exposed to normal atmospheres of cast aluminum or hot dip galvanized steel and finished with two layers of factory applied non-scaling paint.
- N. Construct fans exposed to corrosive atmospheres using all-welded construction of corrosion resistant materials suitable for intended use, and factory finished with epoxy or other approved corrosion resistant coatings.
- O. Provide fans exposed to elevated temperatures with components rated for high temperature service. Do not use belt drive assemblies exposed to the airstream. Use direct drive motors certified for high temperature service.
- P. Use AMCA Type A spark resistant construction for all fans handling flammable or grease-laden vapors, and use explosion proof motors.

- Q. Electrically ground all fans and drives to prevent accumulation of static charge. Indicate grounding method in fan submittals.
- R. Provided threaded drain plugs at fan housing low points.
- S. Completely house fan assemblies exposed to weather in weatherproof enclosures including motor and drive.
- T. Fan wheels/impellers and housings shall be relieved of residual stresses produced in the forming process.
- U. Provide fans used to exhaust grease-laden vapors with motor drive and bearings completely external of air stream, and fan housings continuously welded inside and outside.
- V. Provide housings with integral inlet and discharge flanges, complete with bolt holes for flexible or hard duct connections. Shop fabricate any companion flanges required for connections to sound attenuators. Companion flanges shall be rolled angles matched to both fan housing and sound attenuators.
- W. Provide variable frequency drives as specified in Section 23 05 14 - Variable Frequency Drives.
- X. Provide gasketed access doors to permit routine maintenance and inspection of motor and internal components. Inside surface of access door shall be flush with the inside surface of the fan housing.

2.03 CENTRIFUGAL FANS

A. Scroll Type:

1. Provide backward inclined (BI), backward curved (BC), airfoil (AF), forward curved (FC) fan wheels, and single width single inlet (SWSI), or double width double inlet (DWDI), as specified or indicated on the Drawings, enclosed in a scroll shaped fan housing with shaped cutoff and doors or panels to allow access to internal parts and components.
2. Weld or securely rivet fan blades to the hub plate and rim.
3. Fan housings:
 - a. Heavy gauge construction, continuously welded inside and outside.
 - b. Housings shall be suitably braced to prevent vibration or pulsation and have spun, aerodynamically designed spun inlet cones or inlet venturis for smooth air entry into the wheels.
 - c. Fabrication Class: AMCA 99, Class I [II] [III] [IV].
4. All fan wheels shall have tapered spun wheel cones or shrouds providing stable flow and high rigidity. Housing with lock seam construction or partial weld shall not be acceptable unless for smaller fan sizes (12 inch wheel diameters or less) where it is standard construction for models listed on Drawings.

B. Tubular Type:

1. Construct housing of welded rolled plate steel with reinforcing to prevent distortion. Furnish with streamlined inlet cones and multiple straightening vanes following the fan wheel to minimize noise, reduce turbulence and to impart unidirectional airflow. Provide each housing with a bolted and gasketed access door for inspection of drive and fan wheel. Use non-overloading airfoil blade fans welded to the wheel cones. Isolate belt drives from airstream with a belt tube.
2. Provide brackets suitable for horizontal or vertical mounting. Externally mount motors on an adjustable base.

3. Bearings shall be grease lubricated, self-aligning ball bearing type with grease seal and external grease fitting. Unless a special coating is scheduled, paint fans with a prime coat after metal cleaning and surface preparation. Apply a second coat of paint to all exterior surfaces.
4. Continuously weld fan blades to the hub plate and rim. Backward inclined blades may be securely riveted to the hub plate and rim. Fan wheels shall be precision aluminum castings and machined finished.
5. Match the wheel inlet ring to a close tolerance with integral deep spun aerodynamic venturi inlets.
6. Provide radial airflow straightening vanes at the fan discharge.

C. Cabinet Type:

1. Provide scroll type centrifugal fans, factory installed within a cabinet enclosure, and comply with the requirements of Scroll Type Centrifugal Fans.
2. Internally isolate fan and motor assemblies from the cabinet.
3. Provide gasketed access doors and panels for inspection and routine maintenance of the internal components.
4. Provide solid state variable speed controllers for small ceiling mounted direct driven exhaust and transfer fans.

D. Plug Type:

1. Single width, single inlet air foil type fan blades.
2. Plug fans shall have self aligning pillow block bearings with minimum AFBMA L₁₀ life of 400,000 hours.
3. Plug fan plenums and inlet plenums shall be provided with an expanded metal door locked to prevent access to fan inlet, or a door switch hardwire interlocked to automatically shut down fan operation.

2.04 AXIAL FANS

A. Propeller Type:

1. Include propeller type impellers, complete with motors, and panel or ring mountings.
2. Vary fan blades in camber and twist from base to tip.
3. Construct impellers of die formed steel or aluminum with a welded reinforcing gusset on the backside for added rigidity, attached to a central hub mounted on the fixed drive shaft. Fan shall be of welded and bolted construction utilizing corrosion resistant fasteners
4. Rotate fan hub on the fixed drive shaft using sealed ball bearings with a L₁₀ life of 100,000 hours.
5. To eliminate overhang load on belted fans, design to apply belt load to the hub in the same plane as the bearings.
6. Direct drive fans are only acceptable where belt driven units do not meet the performance criteria or direct drive is specified.
7. Provide panels or rings with spun venturi inlets suitable for wall mounting and structural angle supports of welded steel construction.
8. Provide basket type fan guards for exposed inlets and discharges.
9. Provide TEFC motors on all fans.
10. Provide factory fabricated wall sleeves.

B. Vaneaxial Fixed Blade Type:

1. Include impeller, motor, drive and cylindrical housing.
2. Replaceable fan blades shall have an airfoil cross-section, varying in camber and twist from base to tip, of die-formed steel or aluminum.
3. Fixed pitch fans shall have formed impeller blades and hub in a single precision casting, or precision weld blades to the hub assembly.

4. Mount impeller directly on the drive shaft and secure in place with locking WP assembly. Design motor and impeller to be removable from the inlet side of the fan.
5. Cross brace motor support base on direct drive fans to the fan housing for structural rigidity and to prevent motor misalignment.
6. On belt drive fans, protect belts and bearings from the airstream in an air insulated enclosure. Design to apply belt loads to the hub in the same plane as the bearings to eliminate overhang load.
7. Construct cylindrical fan housings of hot-rolled heavy gauge rolled steel plate with continuous weld seams.
8. Provide venturi inlet bell and discharge diffuser accessories of the same gauge and material as the fan housing.

2.05 ROOF EXHAUST FANS

- A. Provide roof exhaust fans of the centrifugal, belt-driven type. Construct fan housing of heavy gauge aluminum.
- B. Construct all spun parts with a rolled bead for added rigidity and spun so as to seal the pores of the aluminum providing greater resistance against oxidation and deterioration.
- C. Provide all-aluminum fan wheel of the centrifugal blower type backward inclined blades and a tapered inlet shroud. Statically and dynamically balance wheels.
- D. Provide inlet cone of aluminum centrifugal blower type.
- E. Enclose motor and drives in a weather-tight compartment separate from airstream and extend motor leads in metal conduit down through support base to facilitate wiring from below roof. Design to provide air for cooling the motor to the motor compartment by way of an air passage from an area free of contaminated exhaust fumes.
- F. Provide motors of the heavy duty, permanently lubricated, sealed ball bearing type. Size drives for 150 percent of motor horsepower capabilities and of the cast iron type, keyed to the fan and motor shafts. Provide variable pitch drives.
- G. Construct fan shaft of steel construction, turned, ground and polished to precise tolerances in relationship to the hub and bearings.
- H. Provide drive belts of the oil-resistant, non-static, non-sparking type with an ABMA L₁₀ life expectancy of minimum 24,000 hours.
- I. Provide flanged, permanently lubricated and sealed ball or roller type bearings.
- J. The entire drive and wheel assembly shall be removable as a complete unit from the support structure without disassembling the external fan housing. The assembly shall be hinged on one side with full length weatherproof piano hinges. Mount the complete drive assembly on rubber vibration isolation.
- K. Provide direct drive units of identical construction as belt drive units, except for drives, belts, and fan shaft bearings.
- L. Construct all belt drive units interior and exterior parts, including wheel, wheel hub, supporting posts, fan shaft, drive assembly, and all outside fasteners, of aluminum or non-ferrous material. Include a five-year warranty.
- M. Provide a sound-attenuating roof curb with backdraft damper of the same manufacture as the roof exhaust fan.
- N. Upblast units shall have motor, bearings, and drives completely enclosed and isolated from

the exhaust air stream with ventilation provided by outside air. Units handling grease laden vapors to be UL listed for conveying such vapors, operating continuously at 300 degrees F.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Install fans in accordance with manufacturer's recommendations and as shown on the Drawings. Follow SMACNA and AMCA recommended procedures for fan installations, belt guards, duct connections, etc.
- B. Provide flexible connections as described in specification Section 23 31 00 - Ductwork shall provide sufficient separation of ductwork, plenum panels, or air handling unit casings from fan assembly to prevent metal-to-metal contact due to start-up torque or operating under specified isolator deflections.
- C. Install fans and motors with proper support and vibration isolation as specified in Section 23 05 48 - Vibration Isolation and Seismic Restraints.
- D. Provide sufficient clearances around fans for access and servicing of components. Install fans such that tachometer openings, access doors, motors, belts, lubrication lines, electrical connections, etc., are readily accessible and not obstructed by other installations or structures.

3.02 START UP

- A. Verify thermal-overload protection is installed in motors, starters, and disconnect switches. Verify proper motor rotation direction, fan wheel free rotation and smooth bearing operation. Align and adjust belts, install belt guards and verify lubrication for bearings and other moving parts. Verify that manual and automatic volume control and fire/smoke dampers in connected ductwork systems are fully open.
- B. Bump start fans to check that fan wheel/impeller has maintained static and dynamic balance and the rotation corresponds to the desired direction for airflow. Correct fans found to be rotating in a direction opposite to that desired. Unbalanced wheels shall be re-balanced by an AABC - certified test and balance contractor.
- C. Tighten belt drives, taking into account the service factor and any other design of the drive. Exercise care not to overtension belts.
- D. Check all bolts and fasteners to ensure proper tightness. Do not overtighten nuts and bolts.
- E. Check bearings and motor for proper lubrication, taking care not to overlubricate. Use only recommended by the manufacturer.

3.03 FAN ACCESSORIES

- A. Provide the following accessories:
 - 1. Inlet cone, inlet bell, inlet box, inlet screen, inlet vortex breaker
 - 2. Outlet cone, outlet screen
 - 3. Support legs, hanger brackets welded to housing
 - 4. Weatherproof motor and drive cover
 - 5. Shaft seal
 - 6. Backdraft damper
 - 7. Automatic spring loaded belt tensioner on roof mounted ventilators

- B. Provide a drain at the bottom of the housing for fans discharging upward from the roof. Pipe drains from housings of interior fans discharging directly up through the roof indirectly to a floor drain. Pipe drains from housings of kitchen grease exhaust fans to a grease interceptor.
- C. Provide 22-gauge wire mesh reinforced galvanized steel inlet and discharge guard screens for all fans or sound attenuators connected to fans without inlet or discharge ductwork.
- D. Provide shaft seal to reduce leakage and protects the bearings from contaminated airstream. Seal shall be constructed of non-asbestos woven fibrous materials (ceramic felt) compressed between an aluminum cover plate and the fan housing.
- E. Coatings: [Thermoplastic vinyl] [Epoxy] [Zinc] [Synthetic resin] [Phenolic] [Color-match enamel] [Polytetrafluoroethylene] [Vinyl ester] [Hot-dip galvanized] [Powder-baked enamel]; [Insert manufacturer and trade name].
 - 1. Vinyl Coatings Group II and VI: All vinyls shall be thermoplastic material and y resistant to most organic and inorganic acids with medium concentrations and low temperature. Group II – Rustoleum 9000 Series; Group VI – Bisonite M, or equal.
 - 2. Epoxy Coatings Group III-E, VII-S, VII-P and IX: Longer service life than conventional paint against mild acid of caustic solvent. Their resistant characteristics are similar to phenolic. Group III-E – Rustoleum 9100; Group VII-S – Plasite 7122; Group VII-P – Plasite 7133; Group IX – Coal Tar Epoxy; Bitumastic 300-M or Sherwin Williams Sher-Tar Epoxy or equal.
 - 3. Zinc Coating Group III-Z: Cold zinc coating applied as a spray shall provide better corrosion resistance than hot-dip galvanizing and high impact resistance. Zincilate Synthetic Resin Coating (Eisenheiss now called Sanitile) or equal.
 - 4. Group III-S: Low in coat and adequate in resistance to severe acidic and alkaline conditions makes this coating popular for evaporative cooling and other air conditioning equipment. Sanitile or equal.
 - 5. Phenolic Coatings Group IV and VIII: Good resistance to high concentrations of organic or inorganic acids with the exception of strong oxidizing agents, i.e., nitric and chromic. Resistant to only low concentrated alkalis, but excellent solvent resistance. Not recommended for hydrofluoric acid or hypochlorite salts. Air-dried phenolic will have shorter life than baked phenolic. Heresite baked phenolic is most effective while handling dust and explosive gases. Group IV: – Heresite VR500, Group VIII – Heresite P-403, P-4403 or equal.

END OF SECTION

SECTION 23 36 00

AIR TERMINAL UNITS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Fan powered terminal units
 - 2. Variable air volume terminal units
 - 3. Pressure reducing dampers
 - 4. Factory mounted and calibrating control modules, actuators

1.02 SUBMITTALS

- A. Submit manufacturer's leakage rating, certified airflow performance test data, sound performance test data and certified dimensioned drawings.
- B. Submit materials of construction, assembly details and mounting details.
- C. Submit actuators and linkages with control requirements specified.

1.03 REFERENCE STANDARDS

- A. ASHRAE Standard 130
- B. ARI Standard 880
- C. U.L. Standard 1995

1.04 QUALITY ASSURANCE

- A. Electric coils shall be given a 2000-volt dielectric test.
- B. Each size of each device to be used on the project shall be completely laboratory tested for air performance and acoustics. The acceptability of the laboratory and testing facilities is subject to review by the Owner and the Architect.
- C. Pneumatic tubing shall be U.L. listed, fire retardant (F-R) plenum-rated type.
- D. Sound ratings for all units shall not exceed valves specified in Section 23 33 19 - Acoustics at 1-inch water gauge static pressure.
- E. Terminal units shall be listed as a composite assembly per U.L. 1995.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Fan Powered Terminal Units: Titus, Trane, Nailor Industries
- B. Dual Duct and Variable Air Volume Terminal Units: Titus, Trane, Krueger

2.02 FAN POWERED TERMINAL UNITS

- A. Furnish fan-powered terminal devices as indicated on the Drawings. Refer to equipment schedules for duct connection sizes and capacities. Provide the terminal units with a primary variable air volume damper that controls the primary air quantity in response to a control signal. The terminal units shall contain a fan and motor assembly, and [an electric] [a hot water] heating coil where scheduled or indicated on the Drawings. The fan shall provide a constant volume of discharge air at all air-blending ratios from minimum to maximum scheduled primary air quantities and zero to 100 percent return airflow rates. Review the space limitations carefully to ensure all terminal units will fit in the space allowed including National Electric Code clearances required in front of all panels containing electrical devices. Provide an access door or doors to service all internal components and a removable panel to service the fan and electric motor. Provide cam latches for the access doors. Provide a filter rack with a 1-inch thick throwaway filter. Filter shall be replaced prior to building occupancy. The terminal units shall include all equipment and controls as required to provide a complete and operating system with the following minimum equipment and controls:
1. Single point electrical connection for the voltage/phase as scheduled. Refer to Electrical Drawings and specifications for power wiring requirements.
 2. Circuit breaker or fused disconnect switch sized to protect all terminal unit electrical components.
 3. Individual electrical overcurrent protection devices as required to protect individual terminal unit devices and transformers.
 4. A fan speed control system shall be furnished by the terminal unit manufacturer to manually set the fan speed. Speed controller shall be continuously adjustable from maximum to minimum. Match speed control device to operate with the motor. Provide relays to start or stop the fan motor on a signal from the BMS.
 5. Fan motor assembly shall be a forward curved centrifugal fan with a direct drive motor. Motors shall be General Electric ECM variable-speed direct current brushless motors specifically designed for use with a single phase, 277-volt, 60-hertz electrical input. Motor shall be complete with and operated by a single-phase integrated controller/inverter that operates the wound stator and senses rotor position to electrically commutate the stator. An integral controller furnished by the terminal unit manufacturer shall provide a signal to the "ECM" motor to maintain constant supply airflow. All motors shall be designed for synchronous rotation. Motor rotor shall be permanent magnet type with near zero rotor losses. Motor shall have built-in soft start and soft speed change ramps. Motor shall be able to be mounted with shaft in horizontal or vertical orientation. Motor shall be permanently lubricated with ball bearings. Motor shall be direct coupled to the blower. Motor shall maintain a minimum of 70 percent efficiency over its entire operating range. Provide isolation between fan motor assembly and unit casing to eliminate any vibration from the fan to the terminal unit casing. Provide anti-back rotation system or provide a motor that is designed to overcome reverse rotation and not affect life expectancy. Motors and inverter assemblies manufactured by Emerson, General Electric, Fasco, or A.O. Smith shall be acceptable.
 - a. The manufacturer of the fan powered terminal units shall set the fan discharge airflow (cfm) at the factory or in the field. The factory setting for the fan cfm shall be clearly marked on each terminal identification label. If the fan cfm is set in the field by the terminal unit manufacturer the set cfm shall be written on the label in the field by the terminal unit manufacturer's technician. If the fan powered terminal unit manufacturer cannot factory set the fan cfm, factory technicians shall be sent to the field to adjust the motor and the associated controller/inverter to the discharge airflow on the drawings. Fan cfm shall be constant within ± 5 percent regardless of changes in static upstream or downstream of the terminal unit after it is installed in the field. Fan cfm shall be set with a potentiometer and digital meter. Neither SCR's nor rheostats shall be an acceptable means of setting the fan cfm. One speed adjustment device shall be provided by the terminal

unit manufacturer to the Owner for field adjustment of the fan speed should construction or design changes become necessary.

- b. A witnessed test shall be conducted by the fan powered terminal unit manufacturer in an independent testing laboratory to confirm that the terminal unit and the fan motor as an assembly performs in accordance with this specification. If the fan powered terminal device and dc motor as an assembly fails to perform as specified and as scheduled on the Drawings, the terminal unit manufacturer shall make adjustments and take all corrective action as necessary at the terminal unit manufacturer's sole expense.
6. The terminal unit shall be listed in accordance with U.L. 1995 as a composite assembly consisting of the terminal unit with or without the electric or hot water heating device.
- B. Design the primary air damper to vary primary air supply in response to an electronic signal. Damper leakage at shutoff shall not exceed 4 percent of the scheduled maximum fan airflow at 2 inches water gauge. Provide damper connection to the operating shaft of a positive mechanical type to prevent any slippage. Provide non-lubricated delrin or mylar bearings for the damper shaft. Select the primary air damper in conjunction with the DDC microprocessor furnished under Section 23 09 00 - Building Management System (BMS) to provide control at low primary air velocities. The total deviation in primary airflow shall not exceed plus or minus 5 percent of the primary airflow corresponding to a 300 feet per minute air velocity through the primary air valve at 0.2 inches water gauge inlet static pressure. The primary airflow accuracy and repeatability shall be laboratory demonstrated and proven with any inlet configuration and inlet static variation from 0.2 to 2.0 inches water gauge. Dampers shall be life cycle tested to at least 10,000 cycles.
 - C. Sound attenuation of air stream noise and acoustical treatment of terminal unit must comply with Section 23 33 19 - Acoustics with 1 inch water gauge inlet pressure, 0.3 inch water gauge discharge pressure, and the specified design air volume scheduled on the Drawings. Record radiated noise and self-generated noise readings at 0.5, 1.0 and 1.5 inch water gauge inlet static pressures.
 - D. Provide thermal insulation for all portions of the terminal unit in contact with primary cold or fan-powered heated air. Insulation shall be a fiber free product such as closed cell foam that complies with U.L. 181 and NFPA 90A for smoke and flame spread, mechanically fastened to the casing. All cut edges of insulation shall be sealed from the air streams by use of sheetmetal nosings. Exposed fiberglass shall not be accepted.
 - E. Provide a double wall galvanized sheetmetal cabinet with minimum 20 gauge steel outer sheet and perforated 22 gauge inner sheet. Clearly identify on the cabinet mounting connections for hanging the terminal unit by sheetmetal straps. Factory install all components, including all controls and wiring, except the following field connections:
 1. Primary duct
 2. Secondary duct
 3. Single point electrical connection
 4. BMS electronic control signals
 5. Room sensor connection
 - F. The terminal unit shall be designed to provide full cataloged airflow range at an inlet static pressure or 0.25 inches water gauge or less. Downstream static pressure requirements shall be supplied by the unit internal fan.
 - G. The following equipment shall be supplied by Control (BMS) Contractor and installed by the fan powered terminal manufacturer:
 1. DDC microprocessor based controller

2. Pressure transducer if it is not contained in the DDC microprocessor
- H. The Control Contractor shall furnish the DDC unit controller and flow transducers (if not integral with the unit controller) to the terminal unit manufacturer's factory. The Control Contractor shall supply written instructions and drawings containing sufficient information to enable the terminal unit manufacturer to undertake the installation. The terminal manufacturer shall prepare a drawing of the wiring for the terminal unit controller and all associated instrumentation and final control elements based on the information provided by the Control Contractor. The Control Contractor shall visit the terminal unit manufacturer's facility at the completion of the first production run for this Project and prior to the shipping of any units to the project site, to inspect the installation of the DDC controller. The terminal unit manufacturer shall not make any factory adjustments to the DDC unit controller or enter any data into the DDC unit controller in any way. All testing, entry of data and adjustments of any kind to the unit controller shall be undertaken by the Control Contractor at the project site.
- I. GE "ECM" fan motor shall have a multi-point flow sensor factory-installed in each induction port. An averaging flow sensor of equal accuracy may be provided at the fan inlet in lieu of flow sensors at each induction port. U.L. listed (F-R) type tubing shall be factory installed as required for the flow sensors and bulkhead pressure fittings.
 1. 24 volt AC transformer
 2. 24 volt AC fan start/stop relay
 3. 24-volt AC relays for the electric heating coil control through the Division 27 BMS (S) Hot water heating coil control through the BMS.
 4. Manual and/or automatic fan speed adjustment device
 5. Sheet metal enclosure for the DDC controller
 6. Primary air damper and linkage
- J. The terminal unit manufacturer shall verify the operation of each fan-powered terminal before shipment. Testing shall include at least the following:
 1. Apply electric power to the unit.
 2. Start the fan and verify fan rotates properly.
 3. The terminal unit manufacturer shall factory or field adjust the GE ECM motor and associated controller/inverter to the discharge cfm indicated on the Drawings.
 4. Energize the electric heat through the electric heating coil relay. Verify the signal with a volt meter to ensure proper heater operation.
 5. De-energize the electric heating coil and verify the signal with a volt meter to ensure the heater is de-energized.
 6. Disconnect the primary air damper actuator from the DDC terminal unit controller. Provide separate power source to the actuator to verify operation and rotation of damper. Drive the damper closed and verify by feel or observation that damper is driven fully closed. Return primary air damper to the fully open position prior to shipment.
 7. Provide a written inspection report for each terminal unit signed and dated by the factory test technician verifying all terminal unit wiring and testing has been performed per the manufacturer's testing and quality assurance requirements.
- K. The Control Contractor shall provide the terminal unit manufacturer with multi-color point to point wiring diagrams detailing the wiring of the DDC controller and other control equipment installed on the terminal device. The terminal unit manufacturer shall review and approve the wiring diagrams and coordinate any changes necessary with the Control contractor. The terminal unit manufacturer shall incorporate the final version of the wiring diagram in the terminal unit shop drawing submittals.

2.03 VARIABLE AIR VOLUME TERMINAL UNITS – PRESSURE INDEPENDENT PNEUMATIC CONTROL

- A. Provide [single duct] [dual duct] variable volume terminal units of the sizes and capacities

shown on the Drawings.

- B. Provide units of pressure independent pneumatic control with ability to be reset for airflow between zero and maximum airflow. Airflow limiters shall not be accepted.
 - C. At an inlet velocity of 2000 feet per minute, the differential static pressure for any size of unit shall not exceed 0.10 inches water gauge for the basic unit, or 0.25 inches water gauge with sound attenuator added.
 - D. Sound ratings for the unit shall conform to Section 23 33 19 - Acoustics at 1.0 inches water gauge static pressure.
 - E. Equip the unit inlet with a multi-point averaging flow sensor with minimum of four measuring points connected to central averaging chambers. The sensor shall provide a minimum pressure signal of at least .03 inches water gauge at an inlet velocity of 500 feet per minute.
 - F. Design the controller with a 5-pound per square inch reset span regardless of air volume selection. The controller shall modulate the damper actuator through the full range without adding orifices or other parts. The maximum air consumption of the controller shall be 1.2 standard cubic feet per hour at 20 pounds per square inch gauge. Controller action must be field selectable for compatibility with either direct acting or reverse acting thermostats.
 - G. Provide 5 to 10 pound per square inch range actuators, which apply at least 40 inch-pounds of torque to the damper shaft. The damper shall move in a smooth, steady progression, without dead spots.
 - H. Factory set the pneumatic controller and actuator for the maximum and minimum flow rates as scheduled. Include provisions for field calibration and readjustment by both (a) external gauge taps, and (b) maximum/minimum airflow (cfm) dials on the controller.
 - I. The terminal unit shall be suitable for operation with a one or two pipe thermostat.
 - J. Construct the terminal unit casing of 22 gauge galvanized steel, internally insulated. Insulation shall be a fiber free product such as closed cell foam that complies with U.L. 181 and NFPA 90A for smoke and flame spread, mechanically fastened to the casing. All cut edges of insulation shall be sealed from the air streams by use of sheetmetal nosings. Exposed fiberglass shall not be accepted. Seal casing to hold leakage to the maximum of 10 cubic feet per minute at 3 inches water gauge pressure differential.
 - K. Construct damper of heavy gauge metal, with shaft rotating in self-lubricating bearings. Engrave end of shaft to indicate the damper blade position. Design units for field conversion from normally open to normally closed, or vice versa, without relocating the actuator, changing parts or adding relays.
 - L. Provide a built-in stop to prevent overstroking. Damper shall seal against a closed-cell foam gasket, to limit close-off leakage to the maximum of 5 cubic feet per minute at 3 inches water gauge pressure differential.
- 2.04 VARIABLE AIR VOLUME TERMINAL UNITS – PRESSURE INDEPENDENT ELECTRONIC CONTROL
- A. Provide [single duct] [dual duct], variable volume terminal units of the sizes and capacities shown on the plans. The terminal unit shall be listed U.L. 1995 as a composite assembly.
 - B. Provide with pressure independent electronic control capable of reset for airflow between zero and maximum airflow. Airflow limiters will not be accepted.
 - C. At an inlet velocity of 2000 feet per minute, the differential static pressure for any size of

terminal unit shall not exceed 0.10 inches water gauge for the basic unit, or 0.25 inches water gauge with sound attenuator added.

- D. Shaft mount the 24-volt reversible actuator without linkage and construct as an integral part of the electronic controller. The controller/actuator shall operate the terminal unit through the full airflow (cfm) range.
- E. The following equipment shall be supplied by the Control Contractor and installed by the terminal unit manufacturer:
 - 1. DDC microprocessor based controller.
 - 2. Pressure transducer if it is not contained in the DDC microprocessor.
- F. The Controls Contractor shall set the maximum and minimum airflows in the field.
- G. The actuator shall apply at least 35 inch-pounds of torque to the damper shaft. The damper shall move in a smooth, steady progression, without dead spots.
- H. Construct the unit casing of 22 gauge galvanized steel, internally insulated. Insulation shall be a fiber free product such as closed cell foam that complies with U.L. 181 and NFPA 90A for smoke and flame spread, mechanically fastened to the casing. All cut edges of insulation shall be sealed from the air streams by use of sheetmetal nosings. Exposed fiberglass shall not be accepted. Seal casing to hold leakage to the maximum of 10 cubic feet per minute at 3-inch water gauge pressure differential.
- I. Construct damper of heavy gauge metal, with solid metal shaft rotating in self-lubricating bearings. Engrave end of shaft to indicate the damper blade position.
- J. Provide a built-in stop to prevent overstroking. Damper shall seal against a synthetic material gasket, to limit close-off leakage to the maximum of 5 cubic feet per minute at 3-inch water gauge pressure differential.

2.05 VAV AND FAN POWERED TERMINAL UNITS ELECTRIC HEATING COILS

- A. Provide electric heater coils of open coil design constructed of the highest grade 80 percent nickel, and 20 percent chromium resistance wire or nichrome elements and insulated with ceramic, phenolic, or lava insulators in aluminized steel, galvanized steel, or stainless steel brackets, supported in heavy gauge aluminized or galvanized steel frames. Construct each unit containing an electric heating coil and install in accordance with requirements of the local authorities and shall carry U.L. or ETL approval and listing for the terminal unit device with heater.
- B. Refer to the Drawings for coil capacities. Coils rated to 5 kilowatts shall be 277-volt single phase, larger capacities shall 480 volt, three phases. Coils up to 3 kilowatts shall be single step. Coils larger than 3 kilowatts shall be two-step.
- C. Provide terminal bolts, nuts and washers of corrosion resistant materials. Construct coils so the installation may be accomplished in accordance with the provisions of the National Electric Code, for zero clearance. Coils shall receive a 2000-volt dielectric test at the factory.
- D. Provide automatic reset thermal cutouts for primary protection with manual reset limit switches in power circuits for secondary protection. Both devices must be serviceable through terminal box without removing heating element from the terminal unit.
- E. Construct heater with a terminal box and cover containing built-in mercury step controlled contactors for each circuit, branch circuit fusing for each 48 amp circuit per NEC, and a static pressure or airflow safety interlock switch for installation in the heater control enclosure. Use contactors mounted in ceiling above occupied tenant spaces of the mercury type. Provide a separate [120] [24] volt fused control power transformer with primary and secondary

protection and a disconnect.

- F. Bring all wiring of built-in devices to clearly marked terminal strips. Provide a complete wiring diagram permanently attached to the terminal device cover or the terminal device.
- G. Provide electric heater coils designed for operation with the DDC controller and control system as specified in Section 23 09 00 - Building Management System (BMS).
- H. Construct duct heater coils to mount on the discharge of the terminal device.

2.06 VAV AND FAN POWERED TERMINAL UNITS HOT WATER HEATING COILS

- A. Hot water heating coils shall be integrally factory mounted as part of the terminal unit. Coils shall comply with Section 23 82 16 - Hydronic Cooling and Heating Coils.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Maintain service clearance for terminal unit controls.
- B. Stencil all terminal units with nametags on the bottom casing panel to match tags shown on drawings. Lettering/numbering shall be 3 inches high using red primer paint.
- C. Terminal unit manufacturer shall provide flow curves for the primary air sensors clearly label and permanently attached on the bottom or side of each terminal unit.

END OF SECTION

SECTION 23 37 00

AIR OUTLETS AND INLETS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Air Outlets
 - 2. Air Inlets
 - 3. Accessories for Air Inlets and Air Outlets

1.02 SUBMITTALS

- A. Submit manufacturer's performance data including air throw and drop, outlet velocities, total and velocity pressures and acoustic performance.
- B. Submit manufacturer's specifications of construction including materials, installation instruction and adjustment data. Include "K" factors for balancing.
- C. Submit product accessories.
- D. Submit samples, color and finish selections, schedule of sizes and model number for review by the Architect prior to fabrication.
- E. Schedule of air outlets and air inlets indicating drawing designation, room location, quantity, model number, size, and accessories furnished.

1.03 QUALITY ASSURANCE

- A. Air outlets and inlets to be tested in accordance with:
 - 1. ARI 885-90: Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and Air Outlets.
 - 2. ARI 880-94: Air Terminal Test Standard.
 - 3. ANSI/ASHRAE 70-91: Air Diffuser Performance Standard, Isothermal and Cooling.
 - 4. ASHRAE 55-91: Thermal Environmental Conditions for Human Occupancy.
 - 5. ASHRAE 113-90: Method of Testing for Room Air Distribution.
- B. All air inlets and outlets shall be factory painted or anodized. Paint or anodized finish shall pass a 100 hour ASTM D117 Corrosive Environments Salt Spray Test without creepage, blistering or deterioration of film. The finish must pass a 250 hour ASTM-870 Water Immersion Test and an ASTM D-2794 Reverse Impact Cracking Test with a 50 inch-pound force applied. Finish (pencil) hardness shall be minimum HB to H.
- C. For all components provided with fiberglass acoustic lining, refer to Section 23 07 00: Insulation.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Drawings and schedules indicate specific requirements of air inlets and air outlets and are based on the specific requirements of the systems indicated. Other manufacturers' products with equal quality, appearance, finish and performance characteristics may be considered.

Refer to Section 23 05 01 - Mechanical General Provisions for alternates or substitutions.

- B. Air Inlets and Outlets: Titus, Krueger, Price, Air Factors, Air Concepts, Trox, Halton, DuctSox.
- C. Accessories: Dampers, equalizing grids, turning vanes, extractors, plenums, hardware and frames shall be provided by the same manufacturers as the air inlets and air outlets provided.

2.02 GENERAL

- A. Air distribution outlets as shown on the Drawings shall accommodate the air volume and throw indicated to maintain a maximum terminal velocity of 50 feet per minute in the occupied area. The overall noise level produced by all of the supply air outlets and exhaust or return air inlets in various rooms shall not exceed specified limits.
- B. Refer to Architectural Drawings and Specifications for reflected ceiling plans, elevations, wall and ceiling types and construction. Air outlets and inlets in fire rated ceilings or walls must be all steel construction. Coordinate frame and border types to accommodate the wall or ceiling specified or shown on the Architectural Drawings.
- C. All dampers provided shall be operable from the face of the Air Inlet or Air Outlet.
- D. Model numbers noted herein are Titus unless otherwise noted.

2.03 OUTLET TYPES

- A. Square Ceiling Diffuser, Louver Face Fixed Pattern:
 - 1. Provide louver face supply diffusers, all steel construction with AG-75 steel opposed blade volume control damper.
 - 2. Diffuser shall have three one-piece precision die-stamped cones to provide uniform appearance if different neck sizes are used. The back cone shall include an integral drawn inlet. The two inner cones shall be a removable assembly with adjustable vanes to change the airflow from fully open to fully closed.
 - 3. Sizes indicated on Drawings are neck sizes.
 - 4. Baked white enamel finish.
 - 5. Type CD-~~DA~~: 24-inch by 24-inch face size. Titus Model ~~TMSA-OMNI~~ or approved equal.
 - 6. Type CD-~~EB~~: 12-inch by 12-inch face size. Titus Model ~~OMNI/TMSA~~ or approved equal.

~~F. Round Ceiling Diffuser:~~

- ~~1. Provide round face diffusers, all steel construction with AG-75 steel opposed blade volume control damper.~~
- ~~2. Diffusers shall have four cones and round neck, constructed of minimum 18 gauge steel.~~
- ~~3. The airflow discharge pattern shall be field adjustable by extending or retracting the three inner cones with adjusting screws.~~
- ~~4. The three inner cones shall be an easily removable assembly using a spring lock mechanism. Provide safety chain.~~
- ~~5. Sizes indicated on Drawings are neck sizes.~~
- ~~6. Baked white enamel finish.~~
- ~~7. Type CD-F: Titus Model TMRA (Type 1) or approved equal.~~

~~G. Round Ceiling or Sidewall Diffuser:~~

- ~~1. Provide round face diffuser with adjustable concentric cones, round neck, all steel construction with steel opposed blade volume control damper.~~
- ~~2. Cones shall be adjustable through 120 degrees spherical throw direction.~~

- ~~3.Sizes indicated on Drawings are neck sizes.~~
- ~~4.Baked white enamel finish.~~
- ~~5.Type CD-G: Air Concepts Model ANC-RD, Seiho Model PK or approved equal.~~

B. Exposed Duct Double Deflection Supply Register:

1. Provide steel border register with rear vertical and front horizontal adjustable air foil type solid aluminum blades.
2. Provide model AG-35 steel opposed blade volume control damper, model AG-45 extractor and install register on a reverse knuckle joint in accordance with SMACNA Manual.
3. Frames shall be 1.25 inches wide, 20 gauge steel with full penetration resistance welds and a steel reinforcement gasket at each corner. Grind welds smooth and countersink all screw holes.
4. Aluminum blades shall be space on 0.75 inch centers and extend completely through the side frame on each side. Blades shall be individually adjustable without loosening or rattling and shall be securely held in place with permanently spring tensioned wire.
5. Baked white enamel finish.
6. Type SR-A: Titus Model 272 RL or approved equal.

~~I.Sidewall Double Deflection Supply Register:~~

- ~~1.All aluminum register with rear vertical and front horizontal adjustable air foil type blades.~~
- ~~2.Provide model AG-35-AA aluminum opposed blade volume control damper, model AG-45 extractor, and Type PF mounting frame.~~
- ~~3.Frames shall be 1.25 inches wide by 0.05 inch thick aluminum, interlocked at the corners and mechanically staked to form a rigid frame with flush joints and countersunk screw holes.~~
- ~~4.Aluminum blades shall be space on 0.75 inch centers and extend completely through the side frame on each side. Blades shall be individually adjustable without loosening or rattling and shall be securely held in place with permanently spring tensioned wire.~~
- ~~5.Baked white enamel finish.~~
- ~~6.Type SR-B: Titus Model 272FL or approved equal.~~

~~J.Linear Supply Diffuser, Bar Type:~~

- ~~1.Provide extruded aluminum linear diffuser for floor, sill or sidewall application.~~
- ~~2.Fixed bars [1/4 inch] [1/8 inch] [7/32 inch] thick and parallel to the long dimension, locked into an extruded aluminum border. Provide rear support bars parallel to the short dimension on maximum 9 inch centers or 6 inch centers for floor application.~~
- ~~3.Air deflection shall be [0 degrees] [15 degrees].~~
- ~~4.Bar spacing shall be [1/4 inch] [1/2 inch] [7/16 inch].~~
- ~~5.Provide one-piece diffuser lengths up to 6 feet. Longer lengths shall be joined with alignment strips and pins to form a continuous appearance with all joints flush.~~
- ~~6.Provide diffuser length, width, air volume border type, frame type and fastening method as shown on the Drawings.~~
- ~~7.Clean anodized finish.~~
- ~~8.Type LD-A: Titus Model CT— [480] [481] [580] [581] [PP-0] [PP-3].~~

C. Linear Supply Diffuser, Slot Type:

1. Provide extruded aluminum linear diffusers with steel pattern controllers.
2. Slot width shall be shown on drawings. [~~1/2 inch~~] [~~3/4 inch~~] [~~1 inch~~].
3. Provide one-piece diffuser lengths up to 6 feet. Longer lengths shall be joined with alignment strips and pins to form a continuous appearance with all joints flush.
4. Number of slots, lengths, air volume border type, frame type, and fastening or mounting type as indicated on the Drawings.
5. The pattern controller shall be an aerodynamically curved "ice-tong" shaped steel

deflector capable of 180-degree pattern adjustment from the face of the diffuser and shall accommodate dampering as required. Maximum pattern controller length shall be 3 feet. Provide multiple sections as required over the full active length of the diffusers.

6. Confirm color and finish with architect. Clear anodized finish.
7. Type ~~LD-B~~ LD-A: Titus Model ~~FL-10~~ ML— [37] [38] [39].

L. Combination Plenum and Linear Slot:

1. ~~Provide all steel linear slot diffuser with insulated plenums.~~
2. ~~Slot widths shall be [½-inch] [¾-inch] [1-inch].~~
3. ~~Assembly shall include factory fabricated plenum, slot diffuser and pattern controller. The maximum air leakage of the assembly shall not exceed 5 percent of the air volume indicated on the Drawings.~~
4. ~~Number of slots, lengths, air volume border type, frame type, and fastening or mounting type as indicated on the Drawings.~~
5. ~~Baked enamel finish.~~
6. ~~Type LD-C: Titus Model MPI— [37] [38] [39] with Titus Model ML— [37] [38] [39].~~

M. Combination Plenum and Linear Slot:

1. ~~Continuous linear slot diffusers shall fully integrate with the ceiling system and be constructed of 1/16 inch minimum extruded aluminum with continuous bar volume and deflection control damper for each slot. Provide continuous 26-gauge steel plenums with ½ inch acoustical lining sized as per manufacturer's recommendation above diffusers with supply air connections as indicated on Drawings.~~
2. ~~The slot diffusers shall have pattern controllers supported with spacer channels in 24-inch (nominal) increments the entire length of the slot. The pattern controllers shall allow infinite adjustments to the air stream at 24-inch intervals relative to the direction of the air stream as well as extending or reducing the air throw as may be required to satisfy job conditions and to provide draft-free air distribution. The slot diffuser shall maintain airflow across the ceiling and shall not "dump" even when airflow is reduced to 10 percent of design air quantities. Fixed of blade type pattern controllers are not acceptable.~~
3. ~~The slot diffusers and air plenum have been tested as a composite assembly for air distribution and noise level performance in both the horizontal and vertical throw applications. All tests have been conducted in full accordance with ASHRAE 70-91 in a laboratory certified by the ARI.~~
4. ~~Type LD-D: Air Factors Model [—].~~

D. Swirl Ceiling Diffuser:

1. Provide swirl supply diffusers.
2. Diffuser shall have manually adjustable air control blades on the diffuser face which are positioned radially. The diffuser face can be fixed to and removed from plenum box by means of a central screw. The plenum box are supplied with a top or side entry.
3. Sizes indicated on Drawings diffuser sizes.
4. Pretreated and powder-coated "pure white" finish.
5. Type CD-C: 24-inch by 24-inch face size. Trox Model TDV or approved equal.

E. High Volume Low Velocity Radial Air Diffuser

1. Provide high volume, low velocity radial air diffuser.
2. Diffuser shall have low velocity hemispherical pattern.
3. Diffuser shall have steel face and back pan.
4. Diffuser shall have 51% net free area.
5. Confirm color and finish with architect.
6. Type CD-D: 24 x 24" face size. Titus Morel Tri-Tec.

2.04 INLET TYPES

A. Ceiling Perforated Register:

- ~~1. Provide all steel construction with Titus model AG-75 steel opposed blade damper.~~
- ~~2. Flush perforated face shall be an exact match in construction, mounting type and appearance to the perforated face air outlets as specified.~~
- ~~3. Perforated face shall be easily unlatchable from the back pan.~~
- ~~4. Face area as shown on the Drawings.~~
- ~~5. Baked white enamel finish.~~
- ~~6. Type ER-A: Titus Model PAR.~~

B. Louvered Register:

- ~~1. Provide all aluminum register for sidewall or ceiling return or exhaust.~~
- ~~2. The single extruded aluminum set of horizontal fixed blades shall be set at 45-degree fixed deflection on 3/4-inch spacing. Blades shall be secured from behind by welding to fixed mullions. Provide a model AG-35 steel opposed blade damper.~~
- ~~3. The extruded aluminum border shall be 0.05 inches thick and 1.2 inches wide, interlocked and mechanically staked at the four corners to form a rigid frame. Corner joints shall be flush and screw holes shall be countersunk.~~
- ~~4. Baked white enamel finish.~~
- ~~5. Type ER-B: Titus Model 3FL.~~

A. Ceiling Perforated Grille:

1. Provide all steel construction. Face area as shown on the Drawings.
2. Flush perforated face shall be an exact match in construction, mounting type and appearance to the perforated face air outlets as specified.
3. Perforated face shall be easily unlatchable from the back pan.
4. Face area as shown on the Drawings.
5. Baked white enamel finish.
6. Type EG-A: Titus Model PAR 24 x 24
7. Type EG-B: Titus Model PAR 12 x 12.

B. Louvered Return Grille:

1. Return grille shall be used for sidewall or ceiling return or exhaust. All aluminum construction with one set of horizontal fixed blades, set at 45-degree fixed deflection, 3/4-inch spacing.
2. Baked enamel finish.
3. Type EG-C: Titus Model 50F 3FL.

E. Door Mounted Transfer Grille:

- ~~1. Provide door mounted grilles of minimum 20-gauge all steel construction.~~
- ~~2. Blades shall be inverted "V" shaped to provide sight proof design and stiffness. Corners shall be all welded, ground smoothed and reinforced with gussets. Countersink screw holes.~~
- ~~3. Verify all sizes as shown on the Drawings or shown on the Architectural door schedule.~~
- ~~4. Type EG-C: Titus Model T-700.~~

PART 3 – EXECUTION

3.01 GENERAL

- A. Drawings indicate general arrangement of ducts, fittings, and accessories to achieve air volume, noise criteria, airflow pattern, throw, and pressure drop. Locations indicated on the

Architectural drawings shall take precedence. For lay-in ceiling panels, locate in the center of the panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

3.02 INSTALLATION

- A. Install air outlet and air inlet with airtight connection to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.
- B. After installation of diffusers, registers, and grilles, inspect exposed finish. Clean exposed surfaces to remove burrs, dirt, and smudges. Replace diffusers, registers, and grilles that have damaged finishes.
- C. Install diffusers, registers, and grilles level and plumb, according to manufacturer's written instructions.
- D. All visible interior surfaces of air inlets shall be factory painted flat black.
- E. All visible exterior surfaces of air inlets or outlets shall be factory painted in a color as selected by the Architect.

END OF SECTION

SECTION 23 40 00

AIR FILTERS AND CLEANERS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
 - 1. Panel filters
 - 2. Medium performance filters
 - 3. High performance filters
 - 4. Filter frames, clips, housings and holding assemblies
 - 5. Filter gauges

1.02 SUBMITTALS

- A. Submit manufacturer's data on Minimum Efficiency Reporting Value (MERV) rating, sizes, pressure drops, maximum velocities and weights of complete units.
- B. Submit materials of construction, joining and fastening details for filters, frames and holding assemblies.
- C. Submit drawings showing arrangement of multiple filter units.

1.03 QUALITY ASSURANCE

- A. All filter efficiencies are stated in MERV performance as described in ASHRAE Standard 52.2-1999, except as noted.
- B. [All filters shall comply with UL 586, UL 181 and UL 900 Class 1 or Class 2 and be listed with the (California) State Fire Marshall.]
- C. Filter coatings shall comply with ASTM D93.
- D. All filters shall comply with NFPA and UL standards for fuel contributed, flame spread and smoke development.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Flat Filters: Flanders/CSC, Cam/Farr, American Air Filter (AAF)
- B. Bag Filters: Cam/Farr, Viledon, American Air Filter, Flanders/CSC
- C. HEPA Filters: Flanders/CSC, Cam/Farr, Purolator
- D. Activated Carbon Filters: Cam/Farr, or approved equal
- E. Absorption Filters: Extraction Systems Inc., or approved equal
- F. Electronic Filters: AAF, CosaTron
- G. Filter Gauges: Dwyer, or approved equal

2.02 TYPE "A" – PANEL FILTERS

- A. Provide [1] [2]-inch thick pleated, lofted, non-woven, reinforced fabric, supported and bonded to a welded wire grid, and enclosed in cardboard frame for all panel filters with a MERV 7 rating.
- B. In locations where "slide-in" side access type is required, install filters with adequate provisions for preventing bypassing of air around ends.
- C. Do not exceed 400 feet per minute filter bank face velocity or as scheduled on the drawings for the maximum scheduled airflow.
- D. Frames shall be 16-gauge galvanized steel, complete with gaskets and spring type positive sealing fasteners.
- E. Initial resistance shall be 0.3 inches water gauge, 0.9 inches water gauge recommended final resistance.

2.03 TYPE "B" – MEDIUM PERFORMANCE PANEL FILTERS

- A. Provide factory assembled filter media with a MERV 8 rating. Provide filter media 4-inches thick with an effective filter media of at least 7 square feet per square foot of filter face area.
- B. Media retainer shall be of welded steel construction, designed to support multiple pleats of filter cartridge against the direction of airflow.
- C. Filters shall consist of permanent 16-gauge galvanized steel frame and factory assembled replaceable filter cartridges, complete with installation accessories.
- D. Provide holding and sealer frames of 16-gauge galvanized steel, equipped with gaskets and four (4) spring type, positively sealing fasteners.
- E. Select the frame to maximize the filter area in the casing. Limit different filter sizes to three total for the project.

2.04 TYPE "C" – HIGH PERFORMANCE FILTERS

- A. Provide filter media of high-density microfine glass fibers laminated to a non-woven synthetic backing to form a lofted filter blanket. Provide media with a MERV rating of [11] [13] [14].
- B. Provide permanent frame of a self-sealing type to facilitate installation and prevent air leakage between the frames. Provide a seal between the frames and the filter cartridge. The filter media shall be self-supporting against the force of the airflow throughout the operating range of 40 to 120 percent of nominal capacity.
- C. Filters shall consist of permanent 16-gauge galvanized steel frame and factory assembled replaceable filter cartridges, complete with installation accessories.
- D. Filters shall be rated UL Class 1.

2.05 TYPE "C1" – HIGH PERFORMANCE RIGID POCKET FILTERS

- A. Air filters shall be extended surface, self-supporting pocket type. Each air filter element shall be rigid in design and remain so regardless of airflow. Filter pockets shall be injection molded into a polyurethane header to ensure leakproof performance. Pockets shall be heat welded to ensure leakproof seams and periphery.
- B. Filter media shall consist of organic synthetic microfibers progressively structured into a

depth-loading design to optimize dust holding capacity and filter life.

- C. Filter media shall not contain binder material and shall be thermally bonded.
- D. Filter media shall be hydrophobic (water repellent) without the need for water repellent binders. Filter media shall operate effectively in up to 100 percent relative humidity.
- E. Filter element shall not require a pre-filter panel to extend service life.
- F. Filter shall have a guaranteed filter life of two years without the need for pre-filter.
- G. Filter media shall have a MERV rating of [11] [14].
- H. The rated filter face velocity shall be 500 feet per minute, with a maximum initial resistance of [0.4] [0.2] inches water gauge for nominal size filter 24 inches by 24 inches by 26 inches.
- I. The filter shall be classified by Underwriters Laboratories Class 2 when tested accordingly to UL Standard 900.
- J. Filter shall fit into filter frames and housings without interfering with downstream components. All filters shall be the same pocket depths.

2.06 FILTER HOUSINGS (Side Access)

- A. Housing shall be factory-fabricated of 16-gauge galvanized steel, welded and properly braced. Provide pre-punched standing flanges shall facilitate field installation.
- B. Housing or holding frame shall be of the same manufacturer as filter media or provided by the air handling unit manufacturer. Coordinate media size with filter rack design. Contractor fabricated housings or filter racks shall not be accepted. Housing assembly shall be suitable for use in duct systems with 3 inches of water gauge static pressure.
- C. Casing and tracks shall be constructed of galvanized or enameled steel or aluminum. Mounting tracks and access doors shall have gaskets to minimize air bypass around the filters.
- D. Provide two doors for access from both sides. Doors shall be hinged 16-gauge galvanized steel equipped with positive sealing, heavy-duty latches and sponge neoprene gaskets. Doors shall not be secured with nuts, bolts, wing nuts, or sheet metal screws.
- E. Standard filter sections provided by air handling unit manufacturers may be used for MERV 11 and 14 filters but will not be accepted for MERV 17 or above filters or activated carbon filters.
- F. Insulate housings where adjacent duct or air handling apparatus is insulated. Insulation shall be contained within a 2-inch thick, double wall steel panel and meet the requirements specified for adjacent duct or apparatus.
- G. Furnish housings MERV 11 and above air filter system with a lever action sealing mechanism to secure media in tracks.
- H. Frames for filter system with MERV 11 and above, and activated carbon filters shall have an integral pre-filter track for installation Type A filter immediately upstream of high efficiency media. Secure pre-filters by means of spring clips or a spring-loaded mechanism. Provide leakproof gaskets between pre-filter media and holding frame.
- I. Universal holding frames shall be constructed with U-type bearing channels, polyester gasketing and positive sealing clips.

- J. Extrusions of heavy gauge anodized aluminum shall be provided with a replaceable woven pile seal for sealing between extrusion and holding frame.

2.07 FILTER GAUGES

- A. Provide filters with direct reading gauges, 4-inch dial type, diaphragm actuated, in a metal case to monitor both primary and secondary filter banks. Dwyer Magnehelic Series 2000 or approved equal.
- B. Provide direct reading gauges, 4-inch dial type, diaphragm actuated, in a metal case with electrical control contacts to provide high-pressure alarm at the BMS. Dwyer Photohelic Series 3000 or approved equal.
- C. Lettering shall be black figures on white background. Provide front recalibration adjustment.
- D. Provide gauges with the following differential ranges in inches water gauge:

| filter | range |
|-------------------|------------|
| MERV 7 to 10 | 0.0 to 1.0 |
| MERV 11 to 12 | 0.0 to 2.0 |
| MERV 13 to 16 | 0.0 to 2.0 |
| MERV 17 and above | 0.0 to 4.0 |
| Activated carbon | 0.0 to 2.0 |
- E. Provide one gauge for each filter bank, suitable for flush or surface mounting. Include an air filter gauge accessory package consisting of mounting bracket, aluminum tubing, two static pressure tips, and vent valves for each gauge.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Reinforce all filter banks and frames by welding the frames together or with galvanized angles or channels, in accordance with the filter manufacturer's recommendations. The maximum deflection at any point shall not exceed ¼-inch with the filter bank operating at a final air pressure drop of 1.2 inches water gauge.
- B. Fully gasket each filter bank to prevent air bypass around the filter sections or between the filter modules. Caulk and seal between the plenum and the holding frame.
- C. Provide complete sets of type 'A' filters for each air-handling unit to be used during the construction phase. The initial set shall be factory installed and each subsequent construction set shall be installed at the direction of the owner or contractor, or when filters reach a maximum air pressure drop of 0.75 inches water gauge.
- D. Provide two (2) complete sets of the filters specified for each [fan coil], [heat pump], [heating and ventilating unit], [air conditioning unit], built up filter bank and air handling unit. Install one set immediately prior to the air balance and testing required by Section 23 05 93 - Mechanical Systems Balancing. The other set shall be delivered to the owner at the time of initial occupancy of the project.
- E. Maintain necessary clearance for changing filters.
- F. Install filter gauge static pressure tips upstream and downstream of filters. Mount gauge on outside of filter housing or filter plenum in accessible location. Install tubing and gauge valves between gauge and sensor tips. Adjust and level each gauge.

3.02 OPERATION

- A. Maximum air velocity through the filter media shall not exceed 100 feet per minute for pleated type filters or a maximum face velocity of 400 feet per minute through the filter bank at the maximum scheduled fan airflow.
- B. Install filter assemblies according to manufacturer's instructions and accepted trade practice. Focus particular attention on sealing against leakage between holding frame, housing, filter headers and filters.
- C. Do not operate the equipment until specified filter media has been installed. Contractor shall be responsible for maintaining the cleanliness of air handling apparatus and air distribution systems during construction through regular inspection and changing of filter media throughout the construction period.

END OF SECTION

SECTION 23 51 00

CHIMNEYS AND VENTS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
1. Self-supporting high temperature chimney, and breechings, including all fittings, structural supports, fastenings, bracing, sealant, shop and field painting, cleanout doors, ventilated wall, floor or roof thimbles, flashing, rain hood, guy wires, seismic restraints and any related items.
 2. Double wall Type B gas vent pipe and fittings including supports, fastenings, bracing, draft hood connector, sealant, rain cap, ventilated wall, floor or roof thimbles, flashing, guy wires, seismic restraints and any related items.
 3. Self-supporting steel AL29-4C gas vent, including all fittings, structural supports, fastenings, bracing, sealant, shop and field painting, roof terminations, flashing, wall terminations, guy wires, seismic restraints and any related items.

1.02 SUBMITTALS

- A. Provide manufacturer chimney and vent draft calculations. Certify that the calculations are based on actual jobsite conditions and are coordinated with “released-for-construction” boiler submittal data.
- B. Provide backpressure, draft and stack diameter calculations for all possible boiler firing combinations.
- C. Submit certification that chimney and vent will withstand maximum system pressure developed by the burner blowers, combustion and the venting system.
- D. Submit certified dimensioned shop drawings, construction details, mounting details, hardware and accessories.
- E. Submit seismic support and restraint calculations.

1.03 QUALITY ASSURANCE

- A. Units shall be UL listed for use with heating equipment burning gaseous, solid or liquid fuels that do not exceed continuous operating flue gas temperature above 1000°F and not exceeding 1400°F under intermittent conditions as defined in NFPA 211.
- B. Units shall be UL listed for use with heating equipment burning gaseous fuels that do not exceed the requirements for type B vent as defined in NFPA 211.
- C. Units shall be UL listed for use with heating equipment burning gaseous fuels that do not exceed continuous operating flue gas temperature above 550°F as defined in NFPA 211.
- D. The venting system shall develop a positive flow adequate to exhaust flue gases to the atmosphere without condensation within the vent or flue gas spillage. The design shall compensate for thermal expansion.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. High Temperature Chimneys: Metalbestos Model PS, Ampco Model VSI-II
- B. Boiler Stacks and Type B Vents: Metalbestos, Ameri-Vent, Ampco
- C. Condensing Gas Vents: Heat-Fab Inc. Model Saf-T CI, ProTech Systems Inc. FasNSeal, Flexmaster Z-Vent III

2.02 HIGH TEMPERATURE CHIMNEYS AND POSITIVE PRESSURE VENTS

- A. Vent shall be double wall with an outer jacket of aluminized steel 0.025-inch thick for up to 24-inch diameter vents and 0.034-inch thick for larger sizes. The inner wall shall be Type 304 stainless steel of nominal 0.035-inch thickness with a minimum 1-inch air space between the 2 metal walls.
- B. Vent shall be installed and supported in accordance with factory recommendations and factory supplied components. Exposed metal protected by a minimum of one coat base and one finish coat of Rust-O-Crylic as manufactured by Rust-Oleum, or approved equal.
- C. Inner pipe joints shall be sealed by use of flange draw bands with captive nuts and bolts, and RTV Silicone Sealant for flue gas temperatures up to 600° F; above this temperature joints shall be sealed with high temperature joint cement as outlined in the installation instructions and supplied by the manufacturer.

2.03 TYPE B GAS VENT

- A. Vent shall be double wall with an outer jacket of galvanized steel 0.025-inch thick for up to 24-inch diameter vents and 0.030-inch for larger sizes. The inner wall shall be 26-gauge aluminized steel with a 1-inch air space between the 2 metal walls.
- B. Vent shall be installed and supported in accordance with factory recommendations and factory supplied components. Exposed metal protected by a minimum of one coat base and one finish coat of Rust-O-Crylic as manufactured by Rust-Oleum, or approved equal.

2.04 CONDENSING GAS VENT

- A. Vent shall be double wall with an outer jacket of Type 430 stainless steel. The inner wall shall be type AL29-4C stainless steel alloy with a minimum 0.15-inch air space between the 2 metal walls.
- B. Vent shall be installed and supported in accordance with the UL listing, manufacturer's recommendations and using manufacturer supplied components.
- C. Inner pipe joints shall be sealed by use of tapered closure system with external hardware, sealant for flue gas temperatures up to 600° F. Penetrations of the inner liner for joint fastening are not permitted.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Comply with local codes, UL listing, NFPA 211 and factory installation requirements. Coordinate chimney and vent requirements with boiler or appliance listing.

- B. Support breeching from structure. Breeching shall not impose load on appliance or chimney.
- C. Install breeching and chimney with positive slope back to the appliance. Provide easily accessible condensate drainage connection, configured to prevent condensation from entering the boiler.
- D. All branch fittings shall be 45° long radius sweep elbow connections in the direction of flue gas flow. All 90° elbows shall be long radius.
- E. Transitions to increase breeching diameter shall be with an increaser fitting angle of 10° maximum. Increase common breeching manifolds at each branch, and locate the connection within the 10° fitting as a “wye” connection.
- F. Coordinate exact dimensions and other requirements of floor, roof, wall and partition penetrations with all other subcontractors.
- G. Roof penetrations shall be suitable for the roof construction shown and shall follow manufacturer’s installation instructions and local codes.
- H. Maintain clearance to combustible or non-combustible construction in compliance with the vent listing.
- I. For condensing gas vents, install vent with ¼-inch per foot slope back to the appliance from the vertical riser. If the vent is a horizontal vent to a wall termination slope from the boiler or appliance down to the wall termination. Provide manufacturer’s condensate drainage connection, configured to prevent condensation from entering the boiler unless boiler is provided with internal condensate drainage as part of its construction and listing.

END OF SECTION

SECTION 23 52 16

GAS FIRED CONDENSING BOILERS

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this section shall include, but is not limited to the following:

1. Boilers
2. Controls and boiler trim
3. Hot water and drain connections
4. Fuel connections
5. Electrical connections
6. Breeching connection
7. Fuel vent connections and piping to outside
8. Factory authorized boiler start-up and inspection

1.02 SUBMITTALS

A. Submit the following for review:

1. Manufacturer's installation instructions.
2. Certified dimensioned shop drawings, materials of construction, thickness of tubes, shell, boilerplate and insulation, manufacturer's descriptive literature, operating instructions, and maintenance and repair data.
3. Boiler factory inspection report.
4. Boiler start-up report to verify performance.

B. Submittals shall include:

1. Boiler-burner units:
 - a. Unit equipment
 - b. Safety devices
 - c. Controls
 - d. Wiring diagrams
2. Performance:
 - a. Fuel efficiency at 100 percent, 75 percent, 50 percent and 25 percent of rated capacity
 - b. Blower motor electrical efficiencies
 - c. Blower fan curve(s)
 - d. Minimum and maximum oil and/or gas pressure at burner
 - e. Maximum stack backpressure boiler can overcome
 - f. Percent of oxygen at 100 percent, 75 percent, 50 percent, and 25 percent of rated capacity
 - g. Percent NO_x at 100 percent, 75 percent, 50 percent, and 25 percent of rated capacity
3. Test reports, as required and specified
4. ASME Certification Stamp
5. Certification from contractor, boiler manufacturer and stack/breeching manufacturer that the boiler(s) will perform as specified under all possible operating conditions with the flue/stack configuration as installed.

1.03 REFERENCE STANDARDS

- A. Published specifications standards, tests or recommended methods of trade, industry or governmental organizations apply to work in this section where cited below:
1. AGA – American Gas Association
 2. ASHRAE – American Society of Heating, Refrigeration and Air Conditioning Engineers
 3. ASME – American Society of Mechanical Engineers
 - 4* FM – Factory Mutual
 - 5* IRI – Industrial Risk Insurers
 4. NBS – National Bureau of Standards
 5. UBC – Uniform Building Code
 6. UL – Underwriters Laboratories
 7. UMC – Uniform Mechanical Code
 8. UPC – Uniform Plumbing Code
 9. [Washington](#) State codes
 10. Local Codes including Air Quality Standards
 11. Local air pollution control criteria
 12. Rules of utility company

1.04 QUALITY ASSURANCE

- A. Provide factory tests to check construction, controls and operation of units.
- B. Provide ~~National Board for ASME~~ boiler inspection prior to shipment and submit copy of inspection report to Architect.
- C. Controls per FM ~~for IRI~~ requirements, [depending on the jurisdiction](#).
- D. In addition to the warranties and guarantees required by Section 23 05 01 - Mechanical General Provisions, provide the following:
1. Twenty (20) year warranty against failure of any component from thermal shock.
 2. Guaranteed minimum fuel efficiency at 75 percent to 100 percent f rated capacity shall be 80 percent.
 3. Guaranteed efficiency at all other operating capacities shall be minimum of 80 percent.

PART 2 – PRODUCTS

2.01 APPROVED MANUFACTURERS

- A. Fulton Pulse Combustion Boilers
- B. Aerco Model KC Boilers
- C. [Cleaver Brookes Clearfire Boilers](#)

2.02 GENERAL DESCRIPTION

- A. Each unit shall be pulse combustion type complete with boiler fittings and automatic controls. The boiler, with all piping and wiring, shall be completely factory assembled as a self-contained unit. Each boiler shall be neatly finished, thoroughly tested and properly packaged for shipping. Boiler design and construction shall be in accordance with Section IV of the

ASME Code for hot water heating boilers with maximum water working pressure of 60 psi AGAL approved as a direct vent boiler, comply to ASME CSD-1 Code requirements and Washington Boiler & Fired Pressure Vessel Safety Orders. The boiler shall also comply with the requirements of FM [and IRI].

2.03 BOILER SIZE AND RATINGS

A. The capacity of each unit shall be as indicated on the drawing schedule.

~~B. Exit flue gas temperature of the boiler shall not exceed [] degrees F gross at maximum rated input and a hot water supply temperature of [] degrees F and return temperature of [] degrees F. The boiler net input shall not exceed [] BTU/HR and the output not less than [] BTU/HR with an OVERALL fuel to water efficiency of [] percent. [For Pulse+ units specified with full modulation add the following: At low fire, based on a 5 to 1 turndown and the same inlet and outlet water temperatures specified above, the unit shall have an overall efficiency of [] percent.]~~

2.04 BOILER DESIGN

A. Boiler shall be firetube design, utilizing the principles of pulse combustion. The boiler, due to the nature of pulse combustion, shall be self-aspirating requiring no forced or induced draft fan to supply air for combustion after ignition. The exhaust decoupler shall be constructed of corrosion resistant corten and shall include a flue gas condensate drain. ~~[For partial condensing applications, such as closed loop reset temperature control, add the following: The combustion chamber exhaust pipes shall be constructed of stainless steel. For full condensing applications, such as domestic hot water, add the following: The combustion chamber, exhaust pipes, and all wetted surfaces shall be constructed of stainless steel.]~~ Adequate openings shall be provided for the waterside of the boiler. The boiler pressure vessel shall be completely insulated, 2-inch minimum, and encased in an 18-gauge metal cabinet with primer and finish coat of paint.

B. The combustor shall be constructed of SA-53B ERW pipe. The pressure vessel shell shall be SA-53B ERW pipe or SA-285 Grade C plate. The heads shall be SA-516 Grade 70 plate. The pressure vessel shall be fully insulated with 2 inches of high temperature insulation.

C. External convection and radiation heat losses to the boiler room from the boiler shall be less than 0.5 percent of the rated input and the boiler shall not contain any refractory or refractory lined furnace or firebox.

D. The boiler shall be designed for operation in the condensing mode, in order to extract latent heat from the water in combustion products, with a minimum OVERALL fuel-to-water efficiency of 87 percent at a return water temperature of 125 degrees F. This efficiency shall be obtained at full rated input capacity of the boiler.

E. The condensing capability shall allow the boiler to be operated without the use of a 3-way valve for boiler supply water temperature reset. No minimum boiler return water temperature or minimum flow rate shall be required. A dry set of contacts shall be provided in the boiler control circuit to allow remote start/stop control at varying supply water temperatures as determined by the EMCS. The standard operating and high limit temperature controls shall be provided in addition to these contacts. Remote alarm contacts shall be provided.

2.05 BOILER FLUE VENTING

A. The boiler shall be AGAL Approved as a Direct Vent Boiler. Conventional chimney or stack shall not be required. Direct venting shall be accomplished with a stainless steel, single wall, Heat Fab vent piping installed in accordance with applicable national and local codes. The boiler shall have the combustion air intake supply ducted with PVC pipe from the outside. Vent tee drain connections shall be provided on all boilers.

2.06 BOILER FITTINGS

- A. Safety valve(s) shall be ASME Section IV approved side outlet type. Their size and number shall be in accordance with Code requirements and set to open at 85 psig.
- B. Temperature and pressure gauge shall be mounted on top of boiler.

2.07 PULSE COMBUSTOR EQUIPMENT

- A. The flame safeguard system shall be Fulton Model RM7800 with LED display module. The control shall provide a 35-second prepurge and postpurge. The control shall maintain a running history of operating hours, number of cycles, and the most recent six flame failures. The control shall have the capability to be connected to a Keyboard Display Module, which will retrieve this information.
- B. The pulse combustor location shall be such that all combustor assembly components are located within water-backed areas. Pulse combustion controls shall be of on/off operative type and are to include:
 - 1. Operating temperature controller for automatic start and stop of the pulse combustor
 - 2. High limit temperature controller with manual reset
 - 3. One low water cutoff probe in boiler shell with manual reset
 - 4. Air safety switch to prevent operation until sufficient prepurge air is assured
 - 5. High flue gas water cut-off switch located in the exhaust decoupler
 - 6. Proof of flame switch to prove combustion
 - 7. Gas pressure regulator shall be furnished factory installed (Upstream pressure not to exceed 10 inches W.C., minimum 7 inches W.C. If upstream pressure exceeds 10 inches W.C. an additional regulator is required).
 - 8. Full modulation combustion control system shall be furnished which shall provide a turndown rate of 5 to 1 over the burner input range from low to high fire. A Yokogawa UT320 control shall be provided for each boiler, which will accept a signal from the boiler supply water temperature via a thermocouple. The supply temperature and setpoint temperature shall be displayed at all times by an LED readout. The control shall also incorporate contacts which will accept an input for remote temperature reset control of the boiler supply water temperature. * The control shall have the capability to communicate with a PLC or personal computer communication link (RS485). Output shall be continuous PID via 4-20 mA current. Retransmission of the operating temperature shall be sent by a 4-20 mA signal as well as to a monitoring station. The reset control and input signal to the boiler shall be provided by others.
- C. All controls to be panel mounted and so located on the boiler as to provide ease of servicing the boiler without disturbing the controls and also located to prevent possible damage by water, fuel or heat of combustion gases. All controls shall be mounted and wired according to AGA requirements. Electric power supply shall be 120 volts, 60 cycle, single phase, 4.0 amps, for control circuit requirements only. No additional electric power shall be required for devices such as forced draft fans. Maximum electrical usage shall be less than 70 watts.

2.08 EMISSIONS

- A. The boiler(s) shall operate with CO emissions less than 50 ppm corrected to 3 percent O₂ and shall operate with NO_x emissions less than 50 ppm corrected to 3 percent O₂ over the entire burner turndown range.

2.09 OPERATING MANUAL

- A. Instructions for installation, operating and maintenance of the boiler shall be contained in a manual provided with each boiler unit.

- B. A wiring diagram corresponding to the boiler shall be affixed to the inside control box cover.

2.10 EXTENDED WARRANTIES

- A. The pressure vessel shall be guaranteed against thermal shock for 10 years when utilized in a closed loop hydronic heating system with a temperature differential of 170 degrees F or less. The boiler pressure vessel shall be guaranteed accordingly without a minimum flow rate or return water temperature requirement. The boiler shall not require the use of flow switches or other devices to ensure minimum flow.
- B. All burner components, including but not limited to forced draft fans, diffusers, burner housings, pilot assemblies, etc., shall be unconditionally guaranteed for 5 years from date of equipment start-up.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Complete structural, mechanical, piping and electrical connections in accordance with manufacturer's installation instructions.
- B. Install boilers as specified and as indicated on Drawings.
 - 1. Provide code-required electrical services clearance for all electrical components.
 - 2. Provide sufficient maintenance and service clearance for replacing boiler tubes, cleaning, and servicing of components.
 - 3. Provide steel channel base of suitable rigidity and strength for attachment of vibration isolators, seismic restraints and anchor bolts.
- C. Boiler Trim:
 - 1. Provide drain valves for:
 - a. Water level controls
 - b. Water columns
 - c. Low water cutoffs
 - 2. Pipe drain valves to nearest floor drain
 - 3. Pipe safety relief valves discharge full size to nearest floor drain
 - 4. Extend gas valves and control relief vents to outside air in a location acceptable to the Architect.

3.02 TESTS AND START-UP

- A. All testing and start-up required shall be executed using each fuel type specified.
- B. After installation is completed:
 - 1. Test boilers hydrostatically to specified working pressure in accordance with ASME recommendations.
 - 2. Test operating and safety controls by firing boiler and raising water temperature and lowering water level.
- C. Provide services of factory representative of boiler and burner manufacturers to:
 - 1. Supervise installation of boilers, burners and controls.
 - 2. Start up and adjust burners and controls for single and multiple boiler operation.

3. Test individual burner controls for proper operation.
 4. Test safety controls for proper operation.
 5. Set burner firing rates for specified conditions including all possible combinations of multiple boiler operation and lead-lag operation.
 6. Adjust burners for optimum fuel-air ratio over entire operating range.
 7. Test boiler safety (or relief) valves.
 8. Test combustion efficiency over full operating range by means of carbon dioxide analysis and exit gas temperature.
 9. Test for NO_x emissions.
- D. Submit written report by boiler-burner manufacturer confirming that safety and operating controls and burners have been properly installed, calibrated and adjusted. ~~[Certify]~~~~[Provide an independent third party source test and certification]~~ that air pollution control standards are being met and NO_x is less than ~~[30 parts per million]~~~~[AQMD standards]~~.
- E. Instruct Owner's designated personnel in operation of equipment for a minimum period of two eight-hour days.
1. Condensing Design — Due to the condensing design capability of the Fulton Pulse Combustion Boilers, there is no minimum return water temperature requirement as there is for non-condensing type boilers. Therefore, if an outside air temperature and hot water supply temperature reset schedule is to be employed, 3-way valves that are typically used for conventional non-condensing boilers can be eliminated and boiler supply water temperature can be reset at the boiler. If this is desired we will simply furnish an open set of contacts in the control circuit for remote boiler start/stop by the EMCS. In this case the EMCS will provide an output to the boiler control circuit to determine at what temperature the boiler will operate and at what temperature the contacts will open and the boiler will cease to operate.
 2. Condensate Trap — For condensing applications please refer to manufacturer's condensate drain kit installation instructions.
 3. Flue Gas Venting — Applicable National Codes for installation requirements are NFPA54/ANSI Z223.1a, National Flue Gas Code, and NFPA/ANSI211, Chimneys, Fireplaces, Vents and Solid Flue Burning Appliances. These codes contain information on Special Gas Vents for category II, III and IV appliances, vent sizing, location, air space clearances to combustibles, and safe insulation practices. In noise sensitive areas, the flue shall be supported in a manner such that vibrations in the flue shall not be transmitted to the building structure. Spring or rubber type isolators may be required.

END OF SECTION

SECTION 23 52 33

PACKAGED WATER TUBE STEAM BOILERS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
 - 1. Boilers
 - 2. Controls and boiler trim
 - 3. Steam and drain connections
 - 4. Fuel connections
 - 5. Electrical connections
 - 6. Breeching connection
 - 7. Barometric dampers
 - 8. Flue gas recirculation assembly
 - 9. Fuel vent connections and piping to outside
 - 10. Factory authorized boiler start-up and inspection

1.02 RELATED DOCUMENTS

- A. Section 15750 - Boiler Stacks and Type B Vents
- B. Section 23 22 33 - Steam Specialties
- C. Section 23 05 01 - Mechanical General Provisions
- D. Section 23 05 13 - Electric Motors
- E. Section 23 05 19 - Meters, Gauges and Thermometers
- F. Section 23 05 23 - Valves
- G. Section 23 05 29 - Supports, Anchors and Sleeves
- H. Section 23 05 48 - Sound and Vibration Isolation
- I. Section 23 05 93 - Mechanical Systems Balancing
- J. Section 23 09 00 - Building Management System (BMS)
- K. Section 23 09 93 - Automatic Control Sequences
- L. Section 23 21 13 - Piping and Accessories
- M. Section 23 21 23 - Pumps
- N. Section 23 25 00 - Water Treatment
- O. Section 23 31 00 - Ductwork
- P. Section 23 51 00 - Prefabricated Boiler Stacks and Breechings
- Q. Division 26 - Electrical

1.03 SUBMITTALS

- A. Submit the following for review:
1. Manufacturer's installation instructions.
 2. Certified dimensioned shop drawings, materials of construction, thickness of tubes, shell, boiler plate and insulation, manufacturer's descriptive literature, operating instructions, and maintenance and repair data.
 3. Boiler factory inspection report.
 4. Boiler start-up report to verify performance.
- B. Submittals shall include:
1. Boiler-burner units:
 - a. Unit equipment
 - b. Safety devices
 - c. Controls
 - d. Wiring diagrams
 2. Performance:
 - a. Fuel efficiency at 100 percent, 75 percent, 50 percent, and 25 percent of rated capacity
 - b. Blower motor electrical efficiencies
 - c. Minimum and maximum oil and/or gas pressure at burner
 - d. Maximum stack backpressure boiler can overcome
 - e. Percent of oxygen at 100 percent, 75 percent, 50 percent, and 25 percent of rated capacity
 - f. Percent NO_x at 100 percent, 75 percent, 50 percent, and 25 percent of rated capacity
 3. Test reports, as required and specified
 4. ASME Certification Stamp
 5. Certification from contractor, boiler manufacturer and stack/breeching manufacturer that the boiler(s) will perform as specified under all possible operating conditions with the flue/stack configuration as installed.

1.04 REFERENCE STANDARDS

- A. Published specifications standards, tests or recommended methods of trade, industry or governmental organizations apply to work in this section where cited below:
1. AGA – American Gas Association
 2. ASHRAE – American Society of Heating, Refrigeration and Air Conditioning Engineers
 3. ASME – American Society of Mechanical Engineers
 - 4* FM – Factory Mutual
 - 5* IRI – Industrial Risk Insurers
 4. NBS – National Bureau of Standards
 5. UBC – Uniform Building Code
 6. UL – Underwriters Laboratories
 7. UMC – Uniform Mechanical Code
 8. UPC – Uniform Plumbing Code
 9. Washington State Codes
 10. Local Codes including Air Quality Standards
 11. Local air pollution control criteria

12. Rules of utility company

1.05 QUALITY ASSURANCE

- A. Provide factory tests to check construction, controls and operation of units.
- B. Provide ASME boiler inspection prior to shipment and submit copy of inspection report to Architect.
- C. Controls per FM requirements.
- D. In addition to the warranties and guarantees required by Section 23 05 01 - Mechanical General Provisions, provide the following:
 - 1. Twenty (20) year warranty against failure from thermal shock.
 - 2. Guaranteed minimum fuel efficiency at 75 percent to 100 percent of rated capacity shall be 80 percent.
 - 3. Guaranteed efficiency at all other operating capacities shall be minimum of 75 percent.

PART 2 – PRODUCTS

2.01 APPROVED MANUFACTURERS

- A. Boiler, Straight Tube: Rite Engineering, Ajax Boiler
- B. Boilers, Flexible Tube: Bryan Steam, Parker Boiler, Cleaver Brooks

2.02 DESIGN REQUIREMENTS

- A. General:
 - 1. Provide complete packaged water tube boiler-burner unit shipped, as a single factory assembled and prewired unit, except for those items that must be removed for shipping clearances. Items removed for shipping clearances must be noted in the proposal and submittals.
 - 2. Provide multiple boiler installations with boiler sequencing controls including staging, pump interlock and lead-lag switching. Refer to Section 23 09 93 - Automatic Control Sequences.
- B. Boiler Construction: Boiler shall be manufactured in strict accordance with ASME Heating Boiler Code, Section IV; shall bear the ASME stamp for maximum pressure of 160 pounds per square inch at 250°F temperature; and comply with all local laws, regulations, and codes having jurisdiction in the area which the boiler installation is located.
- C. Shell: Construct of welded steel boiler plate with adequately sized water legs and tube headers, providing thermally driven internal water circulation without an external circulation source.
- D. Boiler Tubes: Individual tubes shall be easily removed and replaced, without either welding or rolling, and without entry into combustion chamber or any major disassembly of the jacket. Boiler shall have not less than 4 square feet of heating surface per boiler horsepower.
 - 1. Seamless water tubes shall be 2 inches outside diameter, 13-gauge steel, inclined tube design for straight tube boilers.
 - 2. Seamless water tubes shall be 1½ inches outside diameter, 12-gauge steel, six pass serpentine bend design not subject to thermal shock for flexible tube boilers.

- E. Opening and Tappings: Provide adequate number of access panels, plugs, and tappings to facilitate boiler and flame inspection, boiler service, maintenance and cleaning. Entire tube area shall be easily accessible for fireside cleaning. Boiler shall have appropriate connection points for all trim and accessories specified or required.
- F. Jacket: Heavy gauge rust-resistant, zinc coated casing painted with heat resisting primer and lacquer or galvanized zinc coated steel. Jacket shall be constructed with 24-inch maximum width panels for easy removal and reinstallation. An inner membrane wall will be provided to maintain combustion chamber pressurization.
- G. Insulation: Minimum 2 inches thickness of fiberglass or similar insulation to limit all surface temperatures to not more than 50° F above ambient temperature with air velocity of 90 feet per minute passing over the boiler. Front and rear tube sheet plates will be insulated and jacketed.
- H. Boiler Trim: Provide the following boiler trim in accordance with ASME Code requirements and appropriate for the specified operating pressure:
 - 1. ASME Labeled Safety Valve(s) per ASME code
 - 2. One (1) combination temperature and pressure gauge
 - 3. One (1) low water cutoff
 - 4. One (1) auxiliary low water cutoff, manual reset
 - 5. One (1) expansion tank connection
 - 6. Low fire hold temperature aquastat with time delay relay will be provided.
- I. Fuel Burning Equipment:
 - 1. General: Provide a packaged type, flame retention burner, windbox, forced draft fan, motor and drive assembly, built and provided as a standard product of the boiler manufacturer. There shall not be divided responsibility between the boiler and burner manufacturers.
 - 2. The boiler forced draft combustion chamber will be constructed for a positive pressurized forced draft design. The flue discharge pressure will be positive pressure.
 - 3. Burner: Provide a natural gas-electric ignition system of the interruptible type. The burner design shall assure proper fuel-air mixture for smoke-free, constant carbon dioxide operation at all loads.
 - 4. Windbox: Construct of heavy gauge steel plate, design to assure an even supply of air to all quadrants of the burner register.
 - 5. Combustion Chamber: Refractory type constructed of high temperature insulating firebrick, properly insulated from steel base, with manhole opening for access to combustion chamber and burner head. Combustion chambers will utilize a seal lap joint for allowing full pressurization of the firebox. Draft assisted burner type boilers are not acceptable.
 - 6. Fuel Burning Equipment: Designed for firing using natural gas.
 - 7. Oil Burner Piping: Includes pressure regulating devices, oil metering controls, solenoid shut off valves, strainer, etc. Provide gas piping including reducing valves, shut off valves, and other control valves as required.
 - 8. Oil Pump: Provide factory mounted piped and wired base mounted fuel oil pump.
 - 9. Fuel Controls and Safety Equipment: FM approved, containing the automatic gas valve and operator, vent valve, auxiliary gas safety shutoff valve, pilot solenoid valve, pilot ignition assembly, pilot and main gas shutoff valves, pilot and main gas pressure regulators.
- J. Forced Draft Fan: Mounted integral with the windbox and connected in a manner that will allow easy access for maintenance. The boiler manufacturer shall supply and assume full responsibility for the forced draft fan, motor and drive. The fan volume and static pressure shall be capable of firing the boiler at maximum load with sufficient excess air to assure complete combustion. The fan shall be complete with motor starter and electrical controls.

- K. Combustion Control System: Automatic, modulating type, designed to maintain leaving steam pressure within 2 psig of set point and modulate over a range of minimum 8 to 1. Below the modulating range, the system automatically causes the burner to shut down and automatically recycles when leaving water temperature drops below operating setpoint. Do not provide control components that would permit the operator to adjust individually fuel and combustion air flows. Provide a manual/automatic control station to operate the boiler either on manual control or from master control.
- L. Flame Failure System:
1. The Flame Failure and Programming System shall control starting and stopping of the burner, providing pre-purge and post-purge cycles. The burner shall shut down in the event of either pilot or main flame failure. Flame supervision components shall be located on the front of the burner and detect both pilot and main flame. Provide system in compliance with the requirements of FM.
 2. Burner Shutdown shall occur in the event of:
 - a. High temperature
 - b. Low water level (2 controls required, 1 with manual reset)
 - c. Forced draft fan failure
 - d. Ignition pilot flame failure
 - e. Main flame failure
 3. Restart shall only be enabled when all of the above limit conditions are restored to normal positions.
 4. Pilot or main flame failure shall cause the burner to automatically shut off. Manual reset required to resume operation.
- M. Provide a low fire hold aquastat with time delay relay for remote starting cold boilers.
- N. Flue Gas Recirculation System: Provide a flue gas induced or forced recirculation system to reduce the NOx emission below the current standard of the local Air Quality Management District of 20 parts per million corrected to 3 percent oxygen consisting of the following:
1. Flue gas vent extension mounted on boiler flue outlet with duct opening, and tapped mounting boss for the oxygen trim sensor head on large boilers.
 2. Motor and drive assembly mounted on baseplate matching boiler-mounted fan bracket. Fan and motor support bracket shall be welded to boiler shell.
 3. Fan motor starter and controls. Provide fused disconnect.
 4. Firing rate transducer mounted on main flue gas recirculation valve jack-shaft to coordinate system operation with firing rate of boiler or motorized actuator to control fuel-air ratios.
 5. Flue gas temperature limit interlock.
 6. Pneumatic shut off and modulating valves to control flue gas recirculation rate.
 7. Control panel with all interlocks, relays, safeties, indicating lights, and modulation valve position indicator. Controls shall include a differential pressure switch, feedback potentiometer, stack temperature switch, pneumatic air regulator, and current-to-pneumatic transducer as required to achieve NOx control.
 8. Insulate recirculation flue gas piping from the stack vent extension to the burner, size as shown on drawings or as recommended by the boiler manufacturer.
- O. Control panel cabinet shall be furnished as an integral part of the boiler, containing the following controls:
1. Control Power Transformer
 2. Water Temperature Control Operator
 3. High Limit Safety Control
 4. Proof of Air Flow Safety Switch
 5. Manual Fuel Selector Switch

6. Boiler Lead-Lag Sequencer if multiple boilers
7. Modulating fire rate temperature aquastat
8. Relay contacts for enable/disable of the boiler
9. Relay contacts for remote flow switch
10. Flame failure shutdown
11. One pair of fail-open contacts prewired to terminal strip for alarm connection to Building Management System indicating burner shutdown

P. Tests:

1. Hydrostatic Test: Shop-assembled pressure parts of the boiler shall be hydrostatically tested at the factory at a pressure of 150% of the design pressure. The boiler manufacturer shall furnish a manufacturer's Data Report confirming compliance with ASME Code requirements.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Complete structural, mechanical, piping and electrical connections in accordance with manufacturer's installation instructions.
- B. Install boilers as specified and as indicated on Drawings.
 1. Provide code-required electrical services clearance for all electrical components.
 2. Provide sufficient maintenance and service clearance for replacing boiler tubes, cleaning, and servicing of components.
 3. Provide steel channel base of suitable rigidity and strength for attachment of vibration isolators, seismic restraints and anchor bolts.
- C. Boiler Trim:
 1. Provide drain valves for:
 - a. Water level controls
 - b. Water columns
 - c. Low water cutoffs
 2. Pipe drain valves to nearest floor drain.
 3. Pipe safety relief valves discharge full size to nearest floor drain.
 4. Extend gas valves and control relief vents to outside air in a location acceptable to the Architect.

3.02 TESTS AND START-UP

- A. All testing and start-up required shall be executed using each fuel type specified.
- B. After installation is completed:
 1. Test boilers hydrostatically to specified working pressure in accordance with ASME recommendations or provide factory hydrostatic ASME test reports.
 2. Test operating and safety controls by firing boiler and raising water temperature and lowering water level.
- C. Provide services of factory representative of boiler and burner manufacturers to:
 1. Supervise installation of boilers, burners and controls.

2. Start up and adjust burners and controls for single and multiple boiler operation.
 3. Test individual burner controls for proper operation.
 4. Test safety controls for proper operation.
 5. Set burner firing rates for specified conditions including all possible combinations of multiple boiler operation and lead-lag operation.
 6. Adjust burners for optimum fuel-air ratio over entire operating range.
 7. Test boiler safety valves.
 8. Test combustion efficiency over full operating range by means of carbon dioxide analysis and exit gas temperature.
 9. Test for NO_x emissions.
- D. Submit written report by boiler-burner manufacturer confirming that safety and operating controls and burners have been properly installed, calibrated and adjusted. [Provide an independent third party source test and certification] [Certify] that air pollution control standards are being met and NO_x is less than [AQMD standards] [30 parts per million].
- E. Instruct Owner's designated personnel in operation of equipment for a minimum period of two eight-hour days.

END OF SECTION

SECTION 23 57 00
HEAT EXCHANGERS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Shell and tube heat exchangers
 - 2. Plate and frame heat exchangers

1.02 SUBMITTALS

- A. Submit dimensioned construction shop drawings including certified performance data for each heat exchanger.
- B. Shipping, installed, and operating weights.
- C. Furnished specialties; and accessories for each type of product indicated.
- D. Submit manufacturer's latest published data for materials of construction and installation.
- E. Indicate dimensions, loads, required clearances, method of field assembly/disassembly, components, and location and size of each field connection.

1.03 QUALITY ASSURANCE

- A. All heat exchangers shall be built in accordance with the ASME Unfired Pressure Vessels Code, latest edition, and be stamped with symbol "U", and carry an ASME inspection certificate.
- B. Units tested at a minimum of 1.5 times maximum system working pressure at full differential pressures for those exchangers rated at greater than 250 pounds per square inch working pressure, and 1.5 times maximum system working pressure for those exchangers rated at or less than 250 pounds per square inch. Unit must receive certified factory inspection prior to shipment. Furnish a copy to the Owner of the inspection report Form U-1 signed by a qualified inspector holding a National Board Commission certifying construction conforms to latest ASME Code.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Shell and Tube: Armstrong, Yula, Patterson-Kelley, Bell & Gossett, Taco, BAC
- B. Plate and Frame: APV, Alfa-Laval, Tranter, Mueller, Armstrong, Bell & Gossett

2.02 SHELL AND TUBE HEAT EXCHANGERS

- A. Obtain performance indicated on the drawings. Overall dimensions shall not exceed those indicated on the Drawings.
- B. Construct shells of rolled steel or steel pipe ASME-rated for operating pressure and temperature as specified or shown on the drawings. Provide all necessary connections for incoming and outgoing fluid, drains, vents, reliefs, thermometer and temperature control bulb

wells. Heads shall be cast iron or steel.

- C. Coolers shall be of straight tube type with approved provisions for expansion and designed for cooled water flow. Shells shall be equipped with baffles as required. Except as otherwise indicated or specified, tubes to be of ¾-inch diameter, No. 18 BWG seamless drawn copper or inhibited admiralty metal, securely expanded into tube sheets with ample intermediate supports. Exchangers shall be designed to take up thermal expansion by bowing of the tubes. All tubes shall be arranged in bundles suitable for removal as a unit and for removal of individual tubes.
- D. Provide coolers containing straight tubes with one water box if fluid passing through tube enters and leaves at the same end of the exchanger. Provide two water boxes for other arrangements. Construct water boxes of high-grade cast iron or other material comparable to cast iron in corrosion resistance. Design water boxes for the pressures and temperature of the heat exchanger fluids and provide with all necessary connections and gaskets as specified for flanged heads. Water boxes shall be of channel type with removable cover plate so that both can be removed without dismantling piping.
- E. Construct tube sheets of heavy steel plate, accurately drilled for all tubes.
- F. Provide cast iron or welded steel cradles for mounting of exchangers on approved structural steel frames or concrete piers.

2.03 PLATE AND FRAME HEAT EXCHANGERS

- A. Plate and frame heat exchanger shall be a freestanding assembly consisting of frame support, fixed and movable end plates, tie rods, plates, and one-piece gaskets, constructed of the following materials:
 - 1. Plates: 304 stainless steel with a minimum thickness of 0.8 millimeters.
 - 2. Frame:
 - a. Carbon steel structural frame, consisting of both stationary and movable covers, upper and lower carrying bars, outrigger and compression bolting.
 - b. The frame shall be sized to accommodate 120 percent of the required number of plates.
 - c. Provide brazed assembly consisting of two end plates, one with nozzles, and pattern-embossed plates.
 - 3. Construct the upper Tee-section hanger and the lower guide bar of stainless steel and provide a positive steering and locking mechanism for plate-to-plate alignment.
 - 4. Furnish snap-in nitrile gaskets suitable for the respective maximum system working pressures, temperatures and water treatment of each water system.
 - 5. Carbon steel nozzles shall be rated for 150 percent of maximum system operating pressure and shall be of the flanged type.
 - 6. Install the following items on the units:
 - a. Two lifting lugs located on top.
 - b. Roller assembly on the movable cover for ease of opening.
 - c. Ball bearing assemblies for ease of tightening and untightening the unit.
 - d. Paint all carbon steel fabricated components with epoxy on all exterior surfaces.
 - e. Provide sufficient surface area to perform the specified thermal duty plus additional surface area for fouling as recommended by the equipment manufacturer, but not less than 5 percent additional area.
 - f. Plate-Frame Exchanger shall be equipped with enclosure panels supplied by the unit manufacturer to meet OSHA requirements.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Install heat exchangers according to manufacturer's written instructions.
- B. Install shell-and-tube heat exchangers on saddle supports with provisions to drain shell. Seismically anchor heat exchangers.
- C. Support all piping independently from heat exchangers.
- D. Maintain manufacturer's recommended clearances for service and maintenance. Install piping connections to allow service and maintenance of heat exchangers.
- E. Install shutoff valves at heat exchanger inlet and outlet connections.
- F. Install relief valves on heat exchanger heated-fluid connection.
- G. Install vacuum breaker at heat exchanger steam inlet connection.

3.02 COMMISSIONING

- A. Verify that heat exchangers are installed and connected according to the Contract Documents.
- B. Adjust flows and controls to deliver specified performance.
- C. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

END OF SECTION

SECTION 23 64 26

ELECTRIC SCREW HEAT RECOVERY LIQUID CHILLERS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
1. Design, manufacturer, factory assemble and test, deliver to site, start-up and instruction of operating personnel for the screw type refrigeration machines and starters
 2. Refrigeration machine starters with disconnect switches
 3. Manufacturer's factory representative for start-up and instruction
 4. Testing, start-up and instruction
 5. Operating and maintenance manuals
 6. Refrigerant charge, oil, etc.
 7. System control panel with interface to BMS
 8. Refrigerant gas leak detection system and monitor
 9. Refrigerant recovery system including tank, pump-down compressor, heater, piping, hoses, valves and controls
 10. Automatic condenser cleaning system

1.02 RELATED DOCUMENTS

- A. Section 23 05 01 - Mechanical General Provisions
- B. Section 23 05 48 - Vibration Isolation and Seismic Restraints
- C. Section 23 05 93 - Mechanical Systems Balancing
- D. Section 23 07 00 - Insulation
- E. Section 23 09 00 - Building Management System (BMS)
- F. Section 23 09 93 - Automatic Control Sequences
- G. Section 23 33 19 - Acoustics
- H. Division 26 - Electrical

1.03 SUBMITTALS

- A. Submit in accordance with Division 1 and Section 23 05 01: Mechanical General Provisions.
- B. Product Data:
1. Chiller description and data, addressing all items specified in Part 2 of this Section.
 2. ARI 550-90 certified performance curves (KW input vs. output) for full load, NPLV rated conditions as shown on the Drawings. Any exceptions in entering condenser water temperature for stable and continuous chiller operation must be clearly noted.
 3. Sound power data by octave band at 100, 75, 50 and 20 percent of full load.
 4. Refrigerant gas monitor.
 5. Refrigerant recovery system including tank and controls.
- C. Shop Drawings:

1. Shop drawings of chiller, including dimensions prior to manufacture.
2. Complete wiring diagrams specifically for the proposed equipment. Typical diagrams are not acceptable. Include required wiring between chiller and starter. Indicate locations of conduit connections and connection requirements (number of wires, type of lugs etc.).
3. Structural support for units.
4. Piping size and connection/header location.
5. Electric power requirements and wire, conduit and overcurrent protection sizes.

1.04 REFERENCE STANDARDS

- A. American Refrigeration Institute (ARI):
 1. Unit shall be rated in accordance with ARI Standard 550/590, latest revisions.
 2. Standard 575-87: Method of Measuring Machinery Sound within Equipment Rooms.
- B. American Society of Mechanical Engineers (ASME): Boiler and Pressure Vessel Code (11 Sections – 1980).
- C. American Society for Testing and Materials (ASTM):
 1. Standard C177-85 (R1993): Test Method for Steady State Heat Flux Measurements and Thermal Properties by Means of the Guarded Hot Plate Apparatus.
 2. Standard C335-95: Test Method for Steady State Heat Transfer Properties of Horizontal Pipe Insulations.
- D. Underwriters Laboratories (U.L.)
- E. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE):
 1. ASHRAE 30-95. Methods of Testing Liquid Chilling Packages
 2. ASHRAE 15-94. Safety Code for Refrigeration
- F. National Electric Code (NEC)

1.05 QUALITY ASSURANCE

- A. For refrigeration machines, the scope of work includes piping within the machine up to and including the flanged or rolled-grooved connections for chilled water and condenser water inlet and outlet, control equipment and wiring within the machine including the chilled water and condenser water pressure differential switches, their wiring and wiring of the unit mounted starter. The compressor starter shall be complete with auxiliary oil pump starter, control and instrumentation devices as specified. Provide refrigerant and all lubricants required.
- B. Each chiller shall allow for a water side fouling factor of 0.0001 in the evaporator tubes and 0.00025 in the condenser tubes. Evaporator and condenser water pressure drops shall not exceed those scheduled on the Drawings. The NPLV rating of chiller supplied shall not exceed the NPLV value scheduled on the Drawings.
- C. Unit controls shall be capable of withstanding 150 degrees F storage temperatures in the control compartment.
- D. Furnish for four days for first chiller and one day for each additional chiller a factory trained service engineer, who shall adjust and start the chiller and instruct the Owner's operator on the maintenance and operation of the equipment. The initial charge of the refrigerant and oil for the chiller shall also be supplied. Evacuate, charge and start the refrigeration plant.

- E. Provide manufacturers five (5) years parts and labor warranty on all motor, drive and bearing components, including bearing inspections.
- F. Provide 5 year unconditional parts and labor warranty on purge units.
- G. Provide 2 year unconditional parts and labor warranty on refrigerant, if any is lost due to malfunction of machine.
- H. All warranties are effective from the date of final acceptance of the system.

PART 2 – PRODUCTS

2.01 APPROVED MANUFACTURERS

- A. Screw Chillers: Carrier ~~30HX~~30XW.
- B. Refrigerant Gas Monitors: Yokogawa, General Analysis, Thermal Gas Systems or approved equal.

2.02 ELECTRIC SCREW CHILLERS

- A. Provide factory assembled, single-piece, fluid-cooled or condenser-less liquid chiller with independent refrigerant circuits for each compressor. Contained within the unit cabinet shall be all factory wiring, piping, controls, refrigerant charge (HFC-134a), and any additional components required prior to field start-up.

- B. Compressors shall be semi-hermetic or open drive, rotary screw type.

1. The compressor housing shall be cast iron, precision machined to provide minimal clearance for the rotors. The rotors shall be manufactured from forged steel and use asymmetric profiles operating at a maximum speed of 3570 revolutions per minute.
2. The compressor shall incorporate a complete anti-friction bearing design to reduce power and increase reliability; four separate cylindrical roller bearings to handle radial loads; and two 4-point angular contact ball bearings to handle axial loads. The compressor shall have an internal oil reservoir to insure a constant supply of oil to the bearings at all times.
3. A spring actuated positive seating check valve shall be incorporated in the compressor housing to prevent rotor back-spin during shutdown.
4. The shaft seal shall be a spring loaded carbon ring with precision lapped collar cooled by low pressure oil.
5. Semi-hermetic or open drive twin-screw compressors with internal muffler and check valve.
6. Each compressor shall be equipped with a discharge shutoff valve.

~~7. Chiller manufacturer shall provide a means to service or rewind and replace the motor without disturbing the refrigerant circuit. If the chiller requires opening of the refrigerant circuit to service, rewind, or replace the motor, the manufacturer shall supply a separate refrigerant storage and recovery unit, sized to store the largest refrigerant charge of the largest chiller.~~

- C. Motors:

~~1. Motors shall be semi-hermetic or open drip-proof, squirrel cage, induction type operating at nominal 3600 revolutions per minute. Open motors shall be provided with a NEMA D-flange configuration. A bolted cast iron adapter shall be provided to allow the motor to be rigidly coupled to the compressor, providing factory alignment of motor and compressor shafts, and to allow access to the motor for repair without removing refrigerant charge from the chiller. Chiller design shall prevent refrigerant contamination in the event of motor failure.~~

~~2. Hermetically sealed refrigerant cooled motors shall utilize motor winding temperature RTDs, one per phase, interlocked with the chiller control panel for unit safety shutdown and display of the motor winding temperature at the chiller control panel. Chillers utilizing hermetic motors shall be provided with a ten year guarantee that a motor failure will not contaminate the refrigerant circuit, and if such contamination does occur, the entire refrigerant and oil charge will be replaced at no charge. Additionally, any charges related to the clean up of each unit after such contamination shall be absorbed by the chiller manufacturer at no charge.~~

1. Force-feed lubrication shall be provided to all bearings, gears and rotating surfaces by a positive system pressure differential or full time operation of an oil pump prior to start-up, continuously during operation, and during coast-down of the compressor to insure the bearings are always bathed in oil, even during start-up of the compressor. ~~All chillers shall be provided with a dual oil filter housing with isolation valves to allow immediate switching from one filter to the other, eliminating downtime during filter changes. The off-line filter shall be capable of being changed during chiller operation. The chiller shall ship with two ½ micron absolute oil filters. Monitor oil pressure differential.~~ An immersion oil heater shall be provided, temperature actuated, to effectively remove refrigerant from oil. An oil eductor shall be provided to automatically remove oil which may have migrated to the evaporator and return it to the compressor. The oil separator shall be horizontal design with no moving parts, and shall provide effective oil separation before the refrigerant enters the heat exchangers. The oil separator shall be designed, tested and stamped in accordance with ASME Boiler and Pressure Vessel Code, Section VIII-Division 1. Refrigerant cooled oil coolers shall be supplied and completely factory mounted and piped, including service valves for the oil circuit. Oil circuit piping shall be factory tested for leaks prior to shipping. If alternative water-cooled oil coolers are provided, all additional piping, including service valves, line strainer, and solenoid valve, shall be provided and installed by the chiller manufacturer at no additional cost.

D. Evaporator:

1. The evaporator shell shall be formed of carbon steel plate and shall incorporate a ~~carbon rupture disc or~~ relief valve. End sheets and intermediate tube supports shall be carbon steel and shall be drilled for tube installation. Intermediate tube supports shall be ½ inch thick, spaced a minimum of no more than four feet apart, welded to the vessel shell, and be fully self-supporting.
2. Tubes may be internally and externally enhanced, ~~with an intermediate internal and external skip fin tube design. Skip fin tubes shall be nominal 0.028 inch wall thickness (minimum) and provide 0.053 inch tube wall thickness at the plain lands contacting the intermediate tube supports and end sheets. Alternatively, 0.035 inch wall tubes without skips may be supplied if eddy current tests are provided at 5 year intervals by the chiller manufacturer for the life of the machine.~~ Each tube shall be roller expanded into the tube sheets providing a leak-proof seal, and shall be individually cleanable and replaceable.
3. ~~A suction baffle or aluminum mesh eliminators shall be installed along the entire length of the evaporator to prevent liquid refrigerant carryover into the compressor.~~ A sight glass shall be provided at the evaporator, located such that the proper refrigerant charge is near the center of the glass with the unit off to determine the proper refrigerant level, and not requiring a manufacturer's service technician.
4. Shell shall be tested and stamped in accordance with ASME code for a refrigerant working-side pressure of 220 psig. Waterside pressure rating shall be 150 psig.
5. Shell shall be mechanically cleanable shell-and-tube type with removable heads.
6. Provide rolled groove Victaulic fluid connections.
7. Provide drain and vent connections.
8. Design shall incorporate independent refrigerant circuits for each compressor.
9. Oil Separator for condenserless chillers shall be tested and stamped in accordance with ASME Code for a refrigerant working-side pressure of 320 psig.

E. Condenser and Heat Recovery Condenser:

1. The condenser shell shall be formed of carbon steel-plate. End sheets and intermediate tube supports shall be carbon steel and shall be drilled for tube installation. Intermediate tube supports shall be a minimum 3/8-inch thick, spaced no more than four feet apart, welded to the vessel shell, and be fully self-supporting.
2. Tubes shall be internally ~~and externally enhanced, with an intermediate internal and external skip fin tube design.~~ Skip fin tubes shall be nominal 0.028 inch wall thickness (minimum) and provide 0.053 inch tube wall thickness at the plain lands contacting the intermediate tube supports. ~~Alternatively, 0.035 inch wall tubes without skips may be supplied if eddy current tests are provided at 5 year intervals by the chiller manufacturer for the life of the machine. The eddy current tests are required to ensure protection and long life equivalent to the skip fin tube design.~~ Each tube shall be roller expanded into the tube sheets providing a leak-proof seal. Each tube shall be individually cleanable and replaceable.
3. Shell shall be tested and stamped in accordance with ASME code for a refrigerant working-side pressure of 220 psig. Water- side pressure rating shall be 150 psig.
4. Shell shall be mechanically cleanable shell-and-tube type with removable heads.
5. Provide rolled groove Victaulic water connections.

F. Refrigeration Components:

1. Refrigerant circuit components shall include oil separator, high and low side pressure relief devices, discharge and liquid line shutoff valves, filter drier, moisture indicating sight glass, expansion valve, refrigerant economizer (for sizes over 160 Tons), and complete charge of compressor oil.
2. Provide a complete operating charge of refrigerant, except condenserless chillers shall have a holding charge only.

G. Controls, Safeties, and Diagnostics:

1. Controls shall include the following minimum components:
 - a. Microprocessor with non-volatile memory (battery backup system shall not be accepted)
 - b. Power and control circuit terminal blocks
 - c. ON/OFF control switch
 - d. Replaceable solid-state relay panels
 - e. Thermistor installed to measure saturated condensing temperature, evaporator saturation temperature, compressor return gas temperature, and evaporator entering and leaving fluid temperatures
2. Controls shall include the following functions as standard:
 - a. Automatic chiller lead/lag
 - b. Capacity control based on leaving chilled fluid temperature and compensated by rate of change of return fluid temperature with temperature setpoint accuracy to 0.1 degree F
 - c. Limiting the chilled fluid temperature pull-down rate at start-up to an adjustable range of 0.2 degree F to 2 degrees F per minute to prevent excessive demand spikes at start-up
 - d. Seven-day time schedule
 - e. Leaving chilled fluid temperature reset from return fluid, outdoor-air temperature, space temperature, or 4 to 20 milliamp input
 - f. Demand limit control with 2-stage control (0 to 100 percent each) or through 4 to 20 milliamp input (0 to 100 percent)
 - g. Chilled and condenser water pump start/stop control
 - ~~h. Amperage readout by phase for each compressor~~
3. The control panel shall include a display module with a minimum of 4 lines and 20 characters per line, of clear English language. Display menus shall provide clear

language descriptions of all menu items, operating modes, configuration points & alarm diagnostics. Reference to factory codes shall not be accepted. Display module shall have NEMA 4x housing suitable for use in outdoor environments, backlight & contrast adjustment for easy viewing in bright sunlight or night conditions. Provide raised surface buttons with positive tactile response.

4. The chiller controller shall include multiple connection ports for communicating with the local equipment network and the Building Management System.
5. The control system shall allow software up-grade without the need for new hardware modules.
6. Safety controls shall be equipped with thermistors and all necessary components in conjunction with the control system to provide the following protections:

- a. Loss of refrigerant charge
- b. Reverse rotation
- c. Low chilled fluid temperature
- d. Low oil pressure (each compressor circuit)
- ~~e. Clogged oil filter~~
- e. Voltage imbalance
- f. Ground current fault
- g. Thermal overload
- h. High pressure
- i. Electrical overload
- j. Loss of phase
- k. Current imbalance
- l. Loss of chilled water flow
- ~~n. Loss of condenser flow~~
- ~~o. Loss of Heat Recovery condenser flow~~
- m. Motors shall have inherent over current protection

7. Diagnostics:

- a. The display module shall indicate safety lockout conditions in clear language. Information included for display shall be:
 - (1) Compressor lockout
 - (2) Loss of charge
 - (3) Low fluid flow
 - (4) Low oil pressure
 - (5) ~~Clogged oil filter~~
 - (6) Cooler freeze protection
 - (7) High or low suction superheat
 - (8) Thermistor malfunction
 - (9) Entering and leaving-fluid temperature
 - (10) Evaporator and condenser pressure
 - (11) Electronic expansion valve positions
 - (12) All set points
 - (13) Time of day
- b. Display module, in conjunction with the microprocessor shall be capable of displaying the output results of a service test. Service test shall verify operation of every switch, thermistor, and compressor before chiller is started. User shall be able to force each output device.
- c. Diagnostics shall include the ability to review a list of the 20 most recent alarms with clear language descriptions of the alarm event. Display of alarm codes without clear language descriptions is unacceptable.
- d. An alarm history buffer shall allow the user to store no less than 20 alarm events with clear language descriptions, time & date stamp event entry.

H. Operating Characteristics:

1. Chiller shall be capable of starting with 95 degrees F entering fluid temperature to the cooler.
- ~~2. Chiller shall be capable of extended operation with 60 degrees F entering condenser water temperature and full condenser flow.~~
- ~~3.2.~~ Chiller shall be capable of continuously operating down to 10 percent load. Submit factory certified test data showing operation down to 10 percent load. If the chiller cannot operate continuously down to 10 percent load, the chiller manufacturer shall supply and install an automatic hot gas bypass.

I. Electrical Requirements:

1. Primary electrical power supply shall enter the chiller at a single location.
2. Chiller shall operate on 3-phase power at the voltage shown in the equipment schedule.
3. Chiller shall be shipped with factory control transformer, control power and signal wiring installed.

J. The following factory provided options shall be included:

1. Temperature Reset Sensor: Controls shall reset leaving chilled fluid temperature based on outdoor ambient temperature or space temperature when this sensor is installed.
2. Minimum Load Control: Provide factory (or field) installed, microprocessor-controlled, minimum load control that shall permit operation down to 10 percent of full capacity.
3. Suction Service Valves: Provide factory-installed suction service valves.

~~2.03 COMPRESSOR VARIABLE SPEED DRIVE (VSD):~~

~~A. Chiller variable speed drive shall be factory installed on the chiller factory provided remote mounted designed for top or bottom cable entry. Vary the compressor motor speed by controlling the frequency and voltage of the electrical power to the motor. Adaptive capacity control logic shall automatically adjust motor speed and compressor pre-rotation vane position independently for maximum part-load efficiency by analyzing sensor input located throughout the chiller.~~

~~B. VSD shall be pulse width modulating type utilizing IGBT's with a power factor of 0.95 or better at all loads and speeds.~~

~~C. The variable speed drive shall be unit mounted in a NEMA-1 enclosure with all power and control wiring between the drive and chiller factory installed, including power to the chiller oil pump. Field power wiring shall be limited to a single point connection. Coordinate electrical lug size for incoming power wiring with the Division 26 contractor. The entire chiller package shall be UL listed.~~

~~D. The following features shall be provided:~~

- ~~1. Door interlocked circuit breaker capable of being padlocked~~
- ~~2. UL listed ground fault protection~~
- ~~3. Overvoltage and undervoltage protection~~
- ~~4. 3-phase sensing motor overcurrent protection~~
- ~~5. Single phase protection~~
- ~~6. Insensitive to phase rotation~~
- ~~7. Over temperature protection~~

~~E. Provide digital readout at the chiller control panel of output frequency, output voltage, 3-phase output current, input Kilowatts (kW), Kilowatt-hours (KWh), and self-diagnostic service parameters including the following:~~

- ~~1. Kilowatt Meter: Input power consumption shall be measured and displayed digitally via the~~

- ~~control panel. Meter accuracy shall be plus or minus one percent of reading.~~
- ~~2. Kilowatt-Hour Meter: Cumulative input power consumption shall be measured and displayed digitally via control panel. Meter shall be resettable with an accuracy of plus or minus 2 percent of reading. Meter scale of 0 to 999,999 KWh.~~
 - ~~3. Ammeter: Provide simultaneous three-phase true RMS digital readout via the control panel. Three current transformers shall provide isolated sensing. The ammeter accuracy shall be plus or minus 2 percent of reading.~~
 - ~~4. Voltmeter: Provide simultaneous three-phase true RMS digital readout via the control panel with an accuracy of plus or minus 2 percent of reading.~~
 - ~~5. Elapsed Time Meter: Digital readout of the elapsed running time (0 to 876,600 hours, resettable) shall be displayed via the control panel.~~

~~F. Provide two extra normally open interlocks on the run contactor, overload protection on each of the three phases, fused control circuits, and adjustable time limit acceleration to maximum of 90 seconds. Provide three spare relays and contacts for wiring to the BMS system.~~

~~G. Provide solderless cable connectors for line and load sides. Connectors shall be suitable for copper cable sizes in accordance with applicable electric code wire sizing procedures.~~

~~H. Control transformer shall be sized for the full electric load of all control circuits. In no case shall the control transformer be less than 2 kilovolt-amperes, fused on the primary side.~~

~~I. Distribution Fault: Provide a distribution fault system to protect the chiller from anomalies in the incoming power supply. System shall consist of a sensor on each of the three phases and a monitoring device capable of detecting faults as low as 1.08 electrical cycles in the incoming power supply. System shall disconnect the compressor motor within six cycles of the fault detection.~~

~~J. Provide thermal magnetic molded case circuit breaker type disconnect. Disconnect shall be rated for 100,000 amperes interrupting capacity root mean squared symmetrical minimum at 480 volts. Disconnect shall be mounted in starter enclosure with an externally operable handle.~~

~~K. Provide 480 volt, 3 phase, 60 hertz oil pump motor starter, complete with fuses, 3 phase overload protection and separate 120 volt control. Mount within chiller starter or VSD enclosure.~~

2.03 INSULATION

A. Factory insulated chiller as follows:

1. All cold surfaces of the water chilling unit shall be insulated with ¾ inch thick Armstrong Armaflex II or equal flexible elastomeric closed cell sheet insulation or approved equal. In the case of a uni-shell (cooler/condenser in one shell) vessel, the entire vessel, including the condenser section, shall be insulated. Insulation shall have a K factor not exceeding 0.28 at 75 degrees F mean temperature when tested by ASTM C177 and a water vapor permeability of 0.15 perm-inch or less when tested by ASTM C355 Water Method.
2. Insulation shall be applied to the surface to be insulated with Armstrong 520 adhesive or approved equal over the entire surface. The butt joints shall be sealed with adhesive. The entire Armaflex II insulation installation shall be in accordance with application recommendation "1.1 General" and "1.2.1 Application to Metal Vessel" described in Armstrong Pamphlet IP-698-372Y.
3. The Contractor shall field insulate any areas that show evidence of condensation or sweating during operation. Field insulation shall be the same as the factory insulation.

B. Provide field-installed evaporator insulation that shall cover the evaporator heads.

C. Insulation shall be suitable for outdoor installation.

- D. Insulation end joint material and insulation repairs shall be factory painted to match chiller color.

2.052.04 REFRIGERANT GAS DETECTION SYSTEM

- A. Provide a refrigerant sensitive infrared based stationary refrigerant gas leak monitor system designed to measure the level of refrigerant gas compounds in multiple monitoring areas. The monitor equipment shall be a multiple area, self-contained wall mounted device, with remote air probes located in the airflow path of the area where refrigerant gases are most likely to concentrate. Monitoring system shall support compliance with ANSI/BSR ASHRAE 15-1994 Mechanical Safety Code requirements, and the Uniform Mechanical Code.
- B. The monitor shall be capable of being programmed per application for the selected refrigerant gas per area monitored at the specified accuracy for each refrigerant gas in PPM (parts per million) concentrations as specified in Table "A".
- C. Automatically and continuously monitor for selected refrigerant gas and compare concentrations to user-settable PPM limits per areas monitored, as specified in Table "A".
- D. The monitor shall be of infrared non-dispersive detection type technology with factory calibrated settings for selected refrigerants. Measurement range for refrigerant gas selected shall be as specified in Table "A", with an accuracy as a percentage of full scale in ambient temperature ranges of 32 degrees to 122 degrees F, and 5 percent to 9 percent ambient humidity, (non-condensing).
- E. Adhere to a temperature drift tolerance of 0.3 percent per degree Celsius and have a sensitivity of 1 PPM (parts per million).
- F. Sampling shall be continuous with response time ranges from 5 to 90 seconds, depending on the sample tube length and gas concentration per area measured.
- G. Provide three (3) relays, indicator lights, and digital readout. Standard RS-232C datalink communication port shall be standard with every refrigerant gas monitor unit. Contact terminal for RS-232C interface with DB25 connector port shall be standard.
- H. Display area settings, including the current gas level reading, and the time the reading occurred from the front face panel. An onboard 3½ inch floppy diskette shall record the following data from each area: peak daily leak rate, date, and time of peak. The data shall be in ASCII format for interface with spreadsheet or data processing software.
- I. Two alarm levels shall be provided indicating "alarm" and "spill" conditions. Thresholds for both alarms shall be individually field adjustable with a factory setting of 200 PPM for "alarm" and 300 PPM for "spills". To minimize false alarms, the unit's minimum/maximum alarm and spill levels shall be set at factory recommended settings in accordance with ASHRAE Safety Code 34-1992 allowable exposure levels.
- J. Provide three (3) relays available for additional Owner connections. All relays shall be rated at 120 Volts AC at 5 Amperes AC.
 - 1. ALARM: The Alarm relay connection shall be provided for the addition of an audible or visual warning device. This relay shall "energize" in the event that an area's Alarm level has been exceeded.
 - 2. FAULT: The Fault relay has been provided for an external indicator in the event unit malfunction or failure occurs. If an alarm indicator is attached, normally open to common, the alarm shall be activated in the event of a system fault or malfunction.
 - 3. SPIII: The Spill relay connection shall be provided for the addition of an audible/visual warning device or an exhaust ventilation fan. This relay shall "energize" in the event an area's Spill level has been exceeded.

- K. Power connection to unit shall be provided by Mechanical Division. Power shall be obtained from a junction box in refrigerant plant provided by Division 26. Power consumption shall be less than 200 watts maximum 120 volts AC and be capable of running on 50 to 60 hertz power supply.
- L. Automatically purge monitor with clean air for calibration verification and shall have field-mounted tubing to a clean air source. The monitor system shall require no maintenance other than periodic checking and replacement of filters. Fittings suitable for the connection of ¼ inch O.D. tubing shall be provided on the side of the enclosure of the main monitor unit for the purpose of connecting the air sample and exhaust line.
- M. Access to the monitor shall be secured by key lock to prevent unauthorized personnel from disabling the device. Program shall automatically reset to full function settings allowing power interruption. Provide indicator lamp to denote remote activity. Access to the inside of the enclosure shall be provided through a security key lock device positioned on the monitor front panel. Wiring connections shall be through electrical knock-out ports located on the bottom panel of the enclosure.
- N. Unit shall operate even though a fault occurs. A fault indicator light shall provide operator with indication of a system fault.
- O. The monitor shall be of the sample draw type with an internal pump and filters to draw gas samples to the monitor from a minimum of seven (7) different areas and sequentially measure the gas concentrations from a maximum of 500 feet from each monitoring area. The system shall provide visual alarm indication when preset levels are exceeded. Relay outputs for the purpose of external alarms of control shall be provided. The monitor shall be expandable in three additional groups of 8 sensors up to a minimum of 31 sensors.
- P. The refrigerant monitor shall be ETL listed, or equivalent, and conform to UL Standards 3101.1.
- Q. Provide a combination 100 decibel (at 10 feet) audible alarm horn and a high intensity strobe light (100,000 candlepower peak, 80 flashes per minute) alarm.
- R. Provide Yokogawa Model HGMM200A or approved equal.

| Table "A" | | | | | | | |
|--|---|-----------------------|---------|-----------------|---------|-----------------------------|-------|
| Factory recommended Alarm Set Range and Recommended Settings | | | | | | | |
| Refrigerant | Allowable Exposure level (PPM) ASHRAE 34-1992 | Alarm Set Range (PPM) | | | | *Recommended Settings (PPM) | |
| | | Alarm Set Point | | Spill Set Point | | Alarm | Spill |
| | | Minimum | Maximum | Minimum | Maximum | | |
| HFC: R134a | 1000 | 25 | 990 | 25 | 1000 | 25 | - |

2.05 ACOUSTICAL PERFORMANCE

- A. Sound pressure levels for the complete unit shall not exceed specified levels. Provide the necessary acoustic treatment to the chiller as required. Sound data shall be measured in accordance with ARI Standard 575-87. Data shall be in decibels, referenced to 0.0002 dyne per square centimeter, measured along a perimeter 39 inches from machine and at a height of 60 inches above floor. Data shall be at the highest levels recorded in three (3) operating positions: 100 percent load, 40 percent load and 25 percent load.
- B. The maximum permissible noise level shall not exceed 79 decibels in each octave band when measured as described above.

2.06 CHILLER FULL LOAD AND PART LOAD PERFORMANCE TEST

- A. The proposed chillers shall be run-tested at the manufacturer's factory under 100 percent, 75 percent, 50 percent, and 25 percent load conditions to verify performance (capacity, electrical efficiency, water pressure drops), vibration, operating controls and safety cutouts. The Contractor shall provide to the Architect and Owner a certified test report to confirm that the chiller performs as specified before final payment.
- B. The performance test shall be run in accordance with ARI 550/590-98. If the equipment fails to perform within the tolerances set forth in ARI Standard 550/590-98, the manufacturer shall correct the machine at no additional cost to the Owner and retest. If the machine still fails to perform, the Owner will reject the chiller. The performance test shall be witnessed by the Owner's representatives. The cost of the performance test and Owner's representatives' factory visit including room, meals and weekday travel, and signed report shall be included in the refrigeration machine scope of work.
- C. If the equipment fails to perform within allowable tolerances, the manufacturer will be allowed to make necessary revisions to the equipment and retest as required. The manufacturer shall assume all expenses incurred by the Owner or Owner's Representative to witness the retest.

2.07 REFRIGERANT STORAGE

- A. The condenser shall be capable of storing the entire refrigerant charge during servicing. Isolation from the rest of the system shall be by manually operated isolation valves located at the inlet and outlet of the condenser. Additional valves shall be provided to facilitate removal of refrigerant charge from the system.

2.08 ACCESSORIES

- A. Refrigerant and oil charge: All chillers shall be provided with a full charge of refrigerant and oil.
- ~~B. Flow switches: Chillers shall be supplied with Johnson Controls model F61MG-IC or equal flow switches. Chilled water and condenser water flow switches shall be field installed and wired at an appropriate distance from bends and fittings to minimize turbulent flow at the sensor.~~
- B. Painting: All exposed surfaces and insulation shall be primed using the manufacturer's standard paint system and colors.

2.09 BMS INTERFACE

- A. Status Contacts: Provide one set of normally closed dedicated contacts for each of the following controls to allow remote monitoring:
 - 1. Chiller energized and ready to start when required
 - 2. Anti-recycle timer timing out
 - 3. Chiller not operating due to internal malfunction
 - 4. Chiller not operating due to external malfunction
 - 5. Chiller is running
- B. Chilled Water Reset: Provide a controller to reset the chilled water temperature when provided with an external 4 to 20 milliamp signal. Reset shall be adjustable over a 15 degree range.
- C. Demand Limiting Interface: Provide a controller that will limit the current draw of the motor when provided with an external 0 to 10 volts direct current or 4 to 20 milliamp signal. Demand limiting shall be adjustable from 33 percent to 100 percent of full load.

PART 3 – EXECUTION

3.01 START-UP

- A. Before units are started, pump new grease into bearing housing to force out old grease and provide adequate lubrication.
- B. If factory-mounted oil cooler chilled water piping circuit is not provided, Contractor shall provide field piping as per manufacturer's recommendations including all valves, filters, drains and insulation matching chiller insulation.
- C. Before acceptance of the equipment, all tests shall be conducted as required by demonstrating that the equipment operates mechanically and electrically as specified.
- D. Provide all instruments as required for conducting tests.

3.02 TESTING

- A. The compressors shall be completely assembled at the factory and hydrostatically tested either before or after assembly of shaft and rotor. After assembly the compressor shall be pressure tested with a mixture of refrigerant and air, the casing, joints and connections being tested with an electronic refrigerant detector. After assembly of the complete unit, pressure test the unit with a mixture of refrigerant and air, and all connections and welds tested with an electronic leak detector torch and made refrigerant-tight.

3.03 INSTALLATION

- A. Mount self contained breathing apparatus outside the refrigeration machine room but adjacent to the room entrance, as specified, or as shown on the Drawings.
- B. Provide a legible permanent sign securely attached and accessible outside the refrigeration room entrance. Sign shall have minimum ½ inch high letters and contain the following information:
 - 1. Name, address, telephone number of the installing contractor
 - 2. Type and quality of refrigerant charge
 - 3. Field test pressure
 - 4. Instructions for shutting down the refrigeration system in an emergency
 - 5. Name, address, day and night telephone number for emergency refrigeration service
 - 6. Name, address, telephone number of municipal inspection authority having jurisdiction and instructions on notification procedure in event of a refrigerant leak emergency
- C. Mount refrigerant or oxygen sensors maximum 18 inches above floor in protected locations as shown on the Drawings.
- D. Provide built up concrete pad or steps as required if remote or unit-mounted chiller controls and/or disconnect switch operator does not comply with NEC mounting height or access requirements.
- E. Provide pressure relief discharge piping from relief valve to outdoors. Provide stainless steel flexible connector at chiller. Refer to Drawings. Discharge shall be 15 feet above grade, and 20 feet from any building opening.
- F. Connect purge unit discharge piping into main system pressure relief piping upstream of flexible connector.

END OF SECTION

SECTION 23 65 33

FLUID COOLERS

PART 1 – GENERAL

1.01 DESCRIPTION

- A. General: Provide closed circuit fluid coolers in accordance with the Contract Documents.
- B. In addition to the work covered under this Section, comply with description of individual systems under other Sections of the Specifications.

1.02 SUBMITTALS

- A. Submit sound power levels for each octave band (8 total octave bands) at 5 feet and 50 feet from intake louvers and discharge for locations in front, at side, and directly above fluid cooler.
- B. Submit performance curves for the fluid coolers, showing leaving water temperatures from the cooler for the design temperature range and for temperature ranges corresponding to 80 percent, 60 percent, 40 percent and 20 percent of the design temperature range for wet bulb temperatures of 78 degrees, 75 degrees, 72 degrees, 70 degrees, 65 degrees, 60 degrees, 55 degrees, 50 degrees, 40 degrees and 30 degrees F for design water flow and for 65 percent of design water flow.
- C. Submit seismic restraint calculations for all internally mounted components and for fluid cooler anchoring to supports. Refer to Section 23 05 48 - Vibration Isolation and Seismic Restraints.
- D. Submit materials of construction and certified dimensioned drawings.
- E. Submit fan airflow performance for the as-installed configuration.
- F. Submit certification that motor starter requirements have been coordinated with the Division 16 Contractor including number of speed(s), number of windings, time delay between starts, duty cycle, etc.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Baltimore Air Coil, Evapco.

2.02 COOLING TOWER – FORCED DRAFT TYPE

- A. Provide a forced draft, blow-through, vertical discharge, fluid coolers of sizes and capacity indicated on the Drawings.
- B. Guarantee the fluid coolers to perform as per schedule requirements with the understanding that the building structure in relation to the fluid cooler will be as shown on the Drawings. Maximum drift loss from the tower shall not exceed 0.002 percent.
- C. The coolers shall have centrifugal fan assemblies built completely into the pan, with all moving parts factory mounted and aligned. Unit casing construction shall be heavy gauge hot-dip galvanized steel finished with zinc-chromatized aluminum paint after assembly. Unit basin shall be heavy gauge hot-dip galvanized steel welded construction.

- D. In addition, the coolers shall be provided with electric heaters, sized to maintain basin water at 40 degrees F minimum with ambient air temperatures at -10 degrees F, with factory prewired control junction box for field connection of power wiring for electric water level controller, and variable volume capacity control dampers and controllers, electric pan thermostat and all associated controls. Provide low water level cutout to prevent heater operation unless heater elements are fully submerged.
- E. Pan-Fan Section, Casing: The combination pan-fan section shall consist of galvanized steel channels and sheets of welded construction. Pans shall be galvanized steel 10-gauge angle framework and channels with galvanized 12-gauge panels. Casings shall be galvanized steel 16-gauge. Provide water and airtight manholes in pan section for access into interior of the cooler. Anti-cavitation device and screen shall be provided for all suction sumps. Pans shall include wastewater bleed line with valve, mechanical make-up valve, ladder and handrail as required.
- F. Eliminators: Eliminators shall polyvinyl chloride.
- G. Fans: The forwardly curved centrifugal fans with V-belt drive assembly dynamically balanced. Fans and housings shall be constructed of hot-dip galvanized steel. 18-gauge metal screens shall be provided around entire fan assembly. Provide modulating capacity control dampers with integral vane motor operator for control from a basin water thermostat. Fan motors shall be 460-volt, 60 Hz, 3-phase, totally enclosed, fan cooled. Provide control damper end switch to stop fans.
- H. Water Distribution System: Polyvinyl chloride header with removable branches and plastic self-cleaning spray nozzles. Water/glycol solution shall be distributed uniformly over the coils at a flow rate of not less than 4.5 gallons per minute per square foot of coil cross section.
- I. Provide electrical float switch water level control, low-high water level alarm systems. Electric float switch and controls shall be guaranteed to operate properly in ambient temperatures of -10 degrees F.
- J. Coil Section: The heat transfer section(s) of the fluid cooler(s) shall be encased with hot dip galvanized steel panels and the section(s) shall be removable from the pan. The cooler coil(s) shall be all prime surface steel, tested at 350 pounds per square inch air pressure under water and hot-dip galvanized after fabrication. The coil(s) shall be designed for low-pressure drop with sloping tubes for free drainage of the fluid.
- K. Water Recirculating Pump(s): Pumps shall be close coupled, bronze fitted centrifugal pump equipped with a mechanical seal and shall be mounted on the pan and completely piped to the suction strainer and water distribution system. Pumps shall be installed vertically so that the pump and piping will drain freely when the pan is drained. Pumps shall be sized to meet the cooler capacity as scheduled on the Drawings.

PART 3 – EXECUTION

3.01 SUPPORTS

- A. Steel supports as shown on architectural and structural drawings will be provided by other trades, and any changes, including any engineering and/or architectural fees required for checking of same, required in this steel work to suit the tower furnished under this Section shall be made by the Contractor at his expense.
- B. Steel carrier rail supporting the tower and bearing on vibration isolators shall be provided by this Contractor. Manufacturer shall coordinate beam selection and isolator placement.

END OF SECTION

SECTION 23 73 13

FACTORY ASSEMBLED AIR-HANDLING UNITS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
 - 1. Centrifugal Fan Draw-Through Units
 - 2. Axial Fan Draw-Through Units

1.02 SUBMITTALS

- A. Manufacturer's Data: Submit certified dimensioned drawings, including total weight and support points.
- B. Product Data: Submit fan curves, coil performance and acoustical data for each unit, air pressure drops across each section.
- C. Construction Details: Access doors, drain pans, casing, frame, component mounting arrangements and brackets, connection details, hardware.
- D. Refer to each section listed above in 1.02 - Related Documents for additional submittal requirements.

1.03 QUALITY ASSURANCE

- A. Construct units in compliance with all requirements of the latest edition of the AMCA certified rating standards for air moving equipment: Air and Sound.
- B. Test, rate and certify units' performance and characteristics, including cooling and heating coils, in accordance with ARI.
- C. The [Owner and Architect] [Owner's Representative] may observe the air-handling units for this Project under manufacture at the factory prior to shipment, if they so desire. The Contractor shall notify the [Owner and Architect] [Owner's Representative] in writing of the production schedule and shipment date at least three (3) weeks prior to the first air-handling unit production date.
- D. Provide UL listed electric heating coils.
- E. Sound Ratings: Construct each air-handling unit to operate for all conditions of the air flow (including units serving variable air volume systems from 100 to 15 percent air flow) for installation and sound environment as specified in Specification Section 23 33 19 - Acoustics. Achieve sound rating required for the completed installation with the air-handling unit designed, constructed and installed to comply with the sound power level listed hereinafter with the room construction as indicated on the Architectural and Structural Drawings for this Project, and with the ductwork and vibration isolation Specifications and as indicated on the Mechanical Drawings and in these Specifications.
- F. In order to establish centrifugal fan test curves, test each type of unit in accordance with ARI Standard 430-66.
- G. In order to establish axial fan test curves, test each type of unit in accordance with AMCA Standard 210-85, or the International Standards Organization, Reference BS-848-1980.

- H. Maximum allowable air leakage shall be [1.4] [1.0] percent of design airflow at [4 inches] [1.5 times scheduled] static pressure for the air-handling unit as installed.

PART 2 – PRODUCTS

2.01 GENERAL

- A. Provide factory-built air-handling units of the horizontal or vertical type with the performance requirements and capacities as scheduled and as detailed on the Drawings. Air-handling unit types, as designated on the Drawings, are as follows:
1. Centrifugal Blow-Through
 2. Centrifugal Draw-Through
 3. Axial Blow-Through
 4. Axial Draw-Through
 5. Mixed Flow Blow-Through
- B. Construct each air-handling unit complete with base rails, casings, fans, internal spring type vibration isolation, seismic restraints, insulation, drain pans, heating coils, cooling coils, access doors, lights, economizers, humidifiers, moisture eliminators, air blenders, filters, galvanized or painted filter retainer frames or plenums for filter holding frames and media, control dampers, factory mounted fan motors with adjustable bases, belt guards, and belt drives. The actuators for fans with inlet vanes, plugs or cones shall be electric or electronic type and shall be supplied by BMS contractor to the air-handling unit manufacturer who shall factory install, wire and calibrate the actuator with linkage. Coordinate the power and torque requirements of automatic dampers, inlet vanes, inlet cones, inlet plugs, etc., and other data necessary, with the BMS contractor for the proper selection and coordination of the electric or pneumatic actuators.

2.02 ACCEPTABLE MANUFACTURERS

- A. Air-Handling Units: Temtrol, Trane, Pace, York, Air Systems.
- B. Fan Wheels and Housings, Dampers, Hydronic Coils, Vibration Isolation, Seismic Restraints, Filters, Gauges, Motors, Hardware: Refer to each individual specification section listed above in 1.02 - Related Documents.

2.03 UNIT CASINGS

- A. Construct each unit with an airtight sectionalized casing of phosphatized or bonderized. [Finish phosphatized or bonderized metal with rust-inhibiting paint.] For maximum rigidity properly reinforce casing and brace with steel angle framework with the same finish as the unit casing.
- B. Provide suitable continuous gaskets at all joints between casing sections. Provide stiffeners, if required, to prevent unit casing pulsation or oil canning. Each section shall be modular with identical height, width, and continuous pre-punched matching mating flanges.
- C. Completely enclose all connections, coil headers, and return bends in coil section. Do not use coil frames as structural members of the coil section. Construct the coil section in such a manner that the coils can be easily removed without affecting the structural integrity of the casing.
- D. Extend the drain pans under the complete coil and humidifier sections including access and plenum sections between multiple coils. Pan shall be rigid and watertight with threaded pipe drain connection. Provide drain pans of the double pan insulated type, with a stainless steel inner pan and a galvanized or painted outer pan. Provide UL listed insulation 2-inch thick high-density fiberglass, cemented and vapor sealed between the inner and outer pan, or ½

inch thick foamed-in-place closed cell insulation.

- E. Furnish access doors, [six square feet] [minimum 18 inches wide by 72 inches high] in size, to allow access to all sections. Provide inspection windows in each fan section access door. Equip all doors whose smallest dimensions are twelve inches or less with Amerloc Style 10 or Ventlok Style 100 latch; equip all other doors with Ventlok Style [140] [202] latch and Ventlok Style [150] [260] hinges. Locate doors so that the unit may be inspected or entered regardless of mounting arrangement. Separate door insulation from unit insulation and secure and seal as specified for unit casing insulation. Locate access doors on the most accessible side of the air-handling unit as it is installed on this Project. Provide continuous full height piano hinge for each fan section access door. Fan section door width shall permit removal of fan motor.
- F. Internally insulate unit casings with 4-inch thick, 3-pound density fiberglass with an inner roof and walls of perforated galvanized steel. Floors shall be double wall non-perforated galvanized steel. Cover all exposed parts such as angles, braces, etc., in contact with exterior surfaces with insulation in such a manner to prevent condensation on any surface. Install insulation in such a manner as not to be disturbed if panels are removed. Secure insulation to the casing surfaces and framework with adhesive over entire surface and stik-clips, grip nails or weld pins with fasteners. Protect the insulation from delaminating or fretting by coating edges with adhesive or mastic. Exposed fiberglass shall not be allowed.
- G. Provide weatherproof casing for all air-handling units installed outdoors. Slope roof to rain gutter and arrange all casing seams to eliminate standing water.

2.04 FAN, SHAFT AND DRIVE ASSEMBLIES

- A. Provide [double width, double inlet, multi-blade] [single inlet, multi-blade, un-housed plug type] centrifugal fans with [airfoil] [forward curved] [backward inclined] blades as indicated in the schedule by model or type of fan. Equip units serving variable volume systems with variable frequency drives [inlet vanes/cones/plugs and actuators].
- B. Provide in-line axial fans, direct or belt driven with a belt guard as standard. Construct the fan housing at the wheel raceway and inlet bell to maintain precise tolerance.
- C. Factory assemble fans, sheaves, motors and belts on or within the fan section casing. Supply balanced fans, motors and sheaves. After the factory assembly of the fan, motor and drive, balance air-handling unit fans, bearings and sheaves to meet AMCA Standard 204-96. Units shipped without motors and drives completely assembled shall not be acceptable.
- D. Select fan drives with a minimum belt capacity of [150] [200] percent of the motor nameplate horsepower. Provide the fan drive components as follows:
 - 1. Provide non-adjustable type fan sheaves on air-handling units with variable speed drives with removable machined bushings. Machine the sheaves on all contact surfaces. Dynamically balance fan sheaves with over three grooves. Statically balance fan sheaves with three grooves or less. If weights are required for balancing, weld to the sheave.
- E. Provide variable frequency drives and matching motors as specified in Section 23 05 14 - Variable Frequency Drives and Section 23 05 13 - Electric Motors.
- F. Provide controllable radial inlet vanes plugs for fans serving variable air volume systems. Operate controllable device from a center or perimeter controlling mechanism with machined bronze bearings or ball bearing hubs with nylon bushings or ball bushings. Include a control linkage. Design controllable device suitable for electronic or electric actuator operation. Electric actuator will be provided by Automatic Controls Subcontractor and factory installed, including linkage, by the air-handling manufacturer.

- G. Provide belt guards for all fan drives. Guards shall conform to the contour of the drive assembly. Material, construction, and finish of the guard shall be similar to that of the unit casing. Guards shall be braced and fastened so that objectionable vibration will not occur. Provide tachometer openings at least 2 inches in diameter for checking fan and motor speeds. Tachometer hole must align with the shaft. Two-section fan guards shall be designed in such a manner that either section can be removed without removing the adjacent section.
- H. Motors shall be selected so that they will not overload if the static pressure drops one-quarter inch below the specified value. Motors shall be mounted on the coil connection side unless indicated otherwise on the Drawings. Each motor shall be factory mounted on an adjustable base rigidly supported on the fan base frame. Refer to Section 23 05 13 - Electric Motors and Section 23 34 00 - Fans.

2.05 HYDRONIC COILS

- A. Locate supply and return connections on the same end of the coil.
- B. Provide 16-gauge [galvanized] [Type 304 stainless] steel casings with intermediate stiffeners if over 60 inches in length.
- C. Provide manual air vent connections except on those return connections where the coil header piping is designed to be self-venting. Furnish coils with manual drain connection extended outside the unit casing.
- D. Install heating coils in the reheat position except in outside air preheating units which will be in the preheat position.
- E. Refer to Section 23 82 16 - Hydronic Cooling and Heating Coils.

2.06 ELECTRIC HEATING COILS

- A. Provide UL listed heaters labeled for zero clearance to combustible surfaces and for use with central air conditioning units.
- B. Provide each heater with disc type automatic thermal cutouts for primary protection and load carrying manual reset thermal cutouts for secondary protection.
- C. Provide voltage, phase and number of heating stages as indicated on Drawings. Three phase heaters shall have equally balanced circuits.
- D. Rate heater circuits at 48 amps maximum in accordance with latest edition of National Electrical Code requirements.
- E. Test all heaters dielectrically at 2000 volts before shipment.
- F. Provide with each heater the following items built in and prewired at the factory:
 1. Built-in [electronic] [pneumatic/electric] switches (one for each step), factory prewired to terminal strips for line and control connections in the field. Contactors shall be UL approved for a minimum of 100,000 cycles of operation and one contactor shall be furnished for each heating circuit.
 2. Control transformer, 24 or 120 volts, primary circuit fused if required by UL Standards.
 3. Air flow switch.
 4. Unfused or fused disconnect switch depending upon local code requirements.
 5. Pilot light.
 6. Cover interlock switch.

SECTION 23 73 23

CUSTOM AIR HANDLING UNITS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
 - 1. Air Handling Units - AHU

1.02 RELATED DOCUMENTS

- A. Section 15770 - Humidifiers
- B. Section 23 05 01 - Mechanical General Provisions
- C. Section 23 05 13 - Electric Motors
- D. Section 23 05 14 - Variable Frequency Drives
- E. Section 23 05 19 - Meters, Gauges, and Thermometers
- F. Section 23 05 48 - Vibration Isolation and Seismic Restraints
- G. Section 23 07 00 - Insulation
- H. Section 23 09 00 - Building Management System (BMS)
- I. Section 23 09 93 - Automatic Control Sequences
- J. Section 23 21 13 - Piping and Accessories
- K. Section 23 31 00 - Ductwork
- L. Section 23 33 13 - Dampers
- M. Section 23 33 19 - Acoustics
- N. Section 23 34 00 - Fans
- O. Section 23 40 00 - Air Filters and Cleaners
- P. Section 23 82 16 - Hydronic Cooling and Heating Coils

1.03 SUBMITTALS

- A. Manufacturer's Data: Submit certified dimensioned drawings, including total weight and support points. See Section 23 05 01 for additional submittal requirements.
- B. Product Data: Submit fan curves, coil performance and acoustical data for each unit, air pressure drops across each section. Submit fan curve showing performance.
- C. Construction Details: Access doors, drain pans, casing, frame, component mounting arrangements and brackets, connection details, hardware.

- D. Anchorage Details: Anchorage calculations signed by a California licensed civil or structural engineer. See also Section 23 05 48 - Vibration Isolation and Seismic Restraints.
- E. Acoustical test results and test procedures.
- F. Field leakage test results and test procedures.
- G. Refer to each section listed above in 1.02 - Related Documents for additional submittal requirements.

1.04 QUALITY ASSURANCE

- A. Construct units in compliance with all requirements of the latest edition of the AMCA certified rating standards for air moving equipment: Air and Sound.
- B. Test, rate and certify units' performance and characteristics, including cooling and heating coils, in accordance with ARI.
- C. The Owner's Representative may observe the air-handling units for this Project under manufacture at the factory prior to shipment, if they so desire. The Contractor shall notify the Owner's Representative in writing of the production schedule and shipment date at least three (3) weeks prior to the first air-handling unit production date.
- D. Sound Ratings: Construct each air-handling unit to operate for all conditions of the air flow (including units serving variable air volume systems from 100 to 15 percent air flow) for sound quality environment as specified in Specification Section 23 33 19 - Acoustics. Achieve sound rating required for the completed installation with the air-handling unit designed, constructed and installed to comply with the sound power level listed hereinafter with the room construction as indicated on the Drawings, and with the ductwork and vibration isolation as indicated in these Specifications.
- E. In order to establish centrifugal fan test curves, test each type of fan in accordance with ARI Standard 430-66.
- F. Maximum allowable air leakage shall be 1.4 percent of design airflow at 1.5 times scheduled static pressure for the air-handling unit as installed.

PART 2 – PRODUCTS

2.01 GENERAL

- A. Provide factory-built air-handling units with the components, arrangement, performance requirements and capacities as scheduled and as detailed on the Drawings.
- B. Construct each air-handling unit complete with base rails, casings, fans, internal spring type vibration isolation, seismic restraints, insulation, drain pans, heating coils, cooling coils, sound attenuators, access doors, lights, humidifiers, filters, filter frames, control dampers, backdraft dampers, factory mounted fan motors with adjustable bases, belt guards, and belt drives. Coordinate the power and torque requirements of automatic dampers with the BMS contractor for the proper selection and coordination of the electric actuators.

2.02 ACCEPTABLE MANUFACTURERS

- A. Air Handling Units: Temtrol, Haakon, Climate Craft, or Pace.
- B. Fans, Dampers, Hydronic Coils, Humidifiers, Sound Attenuators, Vibration Isolation, Seismic Restraints, Filters, Gauges, Motors, Variable Speed Drives, Dampers: Refer to each

individual specification section listed above in 1.02 - Related Documents.

- C. The basis of design for equipment specified in this section is the first manufacturer listed. Products of other manufacturer's, named or unnamed, shall be considered as substitutions and submitted in accordance with the requirements for substitutions specified in Division 1.

2.03 UNIT CASINGS

- A. The equipment manufacturer is cautioned to examine all mechanical, structural, and Architectural drawings regarding the intended installation requirements. Coordinate with the contractor to provide proper support and required equipment anchorage for California Seismic Zone IV classification.
- B. Construct each unit with an airtight sectionalized casing of phosphatized or bonderized steel. Finish phosphatized or bonderized metal with rust-inhibiting paint. For maximum rigidity properly reinforce casing and brace with steel angle framework with the same finish as the unit casing. Exterior walls and roof shall be minimum 16-gauge steel.
- C. Inner Liner:
 - 1. Walls and Ceiling: Minimum 20-gauge
 - a. Upstream of cooling coil: Solid galvanized steel.
 - b. Downstream of cooling coil: Solid Type 304 stainless steel.
 - c. Supply fan section and downstream: Perforated galvanized steel.
 - d. Return fan section: Solid galvanized steel.
 - 2. Floor:
 - a. Minimum 14-gauge.
 - b. Upstream of cooling coil: Solid galvanized steel or aluminum treadplate.
 - c. Downstream of cooling coil: Solid stainless steel or aluminum treadplate.
- D. Provide suitable continuous gaskets at all joints between casing sections. Provide stiffeners, if required, to prevent unit casing pulsation or oil canning. Each section shall be modular with identical height, width, and continuous pre-punched matching mating flanges.
- E. Maximum deflection of panels shall be 1/240 of panel length at unit operating pressure. Maximum deflection of floor shall be 1/240 with 150 pounds per square foot live load.
- F. Coating adhesion shall comply with ASTM D-3359-B with no lifting of 1/8-inch squares of coating between scribe lines in cross hatch adhesion testing applied after a 2 x gauge reverse impact. No significant undercutting shall be exhibited on steel panels in a scribed condition after 1,000 hours in 5 percent salt spray testing at 95 degrees F and 95 percent relative humidity as per ASTM B-117. Gloss shall be 20-30 percent at 60 degrees. Film pencil hardness shall be in the F-H range. Film solvent resistance shall withstand 100 double rubs with MEK.
- G. Completely enclose all connections, coil headers, and return bends in coil section. Do not use coil frames as structural members of the coil section. Construct the coil section in such a manner that the coils can be easily removed without affecting the structural integrity of the casing.
- H. Extend the drain pans under the complete coil section including access and plenum sections between multiple coils. Pan shall extend minimum 15 inches downstream and 9 inches upstream beyond face of coil and be minimum 2 inches deep. Pan shall be rigid and watertight with threaded pipe drain connection extended out the side of the unit. Slope pan minimum 0.25 inches per foot in two directions. Provide drain pans of 16-gauge type 304 stainless steel. Provide intermediate drain pans for coils over 48 inches in height.

- I. Furnish access doors, minimum 18 inches wide by 72 inches high in size, to allow access to all sections. Provide inspection windows in each fan section access door. Window shall have double paned tempered glass with an integral desiccant between the hermetically sealed panes. Equip all doors with Ventlok Style 202 (or equal) latch and Ventlok Style 260 (or equal) hinges. Locate doors so that the unit may be inspected or entered regardless of mounting arrangement. Doors shall open against fan pressure or doors shall be provided with a safety latch. Separate door insulation from unit insulation and secure and seal as specified for unit casing insulation. Interior liner of access doors shall be non-perforated. Locate access doors on the most accessible side of the air-handling unit as it is installed on this Project. Fan section door width shall permit removal of fan motor.
- J. Internally insulate unit casings with minimum 4-inch thick, 3-pound density fiberglass sandwiched between the outer and inner casing walls. Cover all exposed parts such as angles, braces, etc., in contact with exterior surfaces with insulation in such a manner to prevent condensation on any surface. Protect the insulation from delaminating or fretting by coating edges with adhesive or mastic. Exposed fiberglass shall not be allowed. Insulation shall meet the erosion requirements of UL 181 facing the air stream. Refer to Section 23 07 00 for additional requirements.
- K. Where indicated on drawings, provide factory installed sound attenuators as required to meet specified sound levels. The sound traps shall be installed to prevent sound from bypassing the sound trap assembly.
- L. Provide weatherproof casing. Slope roof to rain gutter and arrange all casing seams to eliminate standing water. Provide additional gutters above access doors and outdoor air intake louvers.
- M. Provide within the air handling unit-casing footprint a separate enclosure for mounting of variable frequency drives, electrical boxes, and control components. Provide for required code and service clearances. Provide ventilation opening with balancing damper from AHU to maintain enclosure temperature within the operating range of the equipment. Provide variable frequency drives from same manufacturer as all other variable speed drives for this project.
- N. Provide conduit connections between sections for installation of control wiring.
- O. Provide motor removal system to allow removal of motors.

2.04 FAN, SHAFT AND DRIVE ASSEMBLIES

- A. Provide fan wall using direct drive save axial fans.
- B. Factory assemble fans, sheaves, motors and belts within the fan section casing. Supply balanced fans, motors and sheaves. After the factory assembly of the fan, motor and drive, balance air-handling unit fans, bearings and sheaves to meet AMCA Standard 204-96. Fan base shall be spring isolated with separate seismic snubbers and attached to the casing structural frame. Units shipped without motors and drives completely assembled shall not be acceptable.
- C. Provide precision self-aligning bearings designed to prevent leakage of oil or grease. Provide cups, oil chambers, Zerk or Alemite lubrication fittings in accessible locations for ease of lubrication. Provide heavy duty split pillow block bearings with tapered, double-row spherical roller assemblies. Provide bearings with AFBMA L₁₀ service life in excess of 200,000 hours at maximum published fan operating conditions for the AMCA construction class required unless noted or specified otherwise.
 - 1. Provide copper lubrication leads, for lubrication of internal motors and bearings, extending to a capped termination point easily accessible from the fan section access door without

- D. Provide variable frequency drives and matching motors as specified in Section 23 05 14 - Variable Frequency Drives and Section 23 05 13 - Electric Motors. No splices are allowed between VFD and fan motor.
- E. Provide belt guards for all fan drives. Guards shall conform to the contour of the drive assembly. Guards shall be braced and fastened so that objectionable vibration will not occur. Provide tachometer openings at least 2 inches in diameter for checking fan and motor speeds. Tachometer hole must align with the shaft. Two-section fan guards shall be designed in such a manner that either section can be removed without removing the adjacent section.
- F. Motors shall be selected so that they will not overload if the static pressure drops one-quarter inch below the specified value. Motors shall be mounted to allow access for removal through casing access doors. Each motor shall be factory mounted on an adjustable base rigidly supported on the fan base frame. Refer to Section 23 05 13 - Electric Motors and Section 23 34 00 - Fans.

2.05 HYDRONIC COILS

- A. Locate supply and return connections on the same end of the coil.
- B. Provide 16-gauge Type 304 stainless steel casings with intermediate stiffeners if over 60 inches in length.
- C. Provide 0.625-inch copper tubes with 0.025-inch wall thickness with 0.008-inch aluminum fins.
- D. Provide manual air vent connections except on those return connections where the coil header piping is designed to be self-venting. Furnish coils with manual drain connection extended outside the unit casing.
- E. Refer to Section 23 82 16 - Hydronic Cooling and Heating Coils.

2.06 FILTER SECTION

- A. Provide galvanized steel filter sections and retainer frames for Type "C" filters, with Type "A" pre-filters, to accommodate the specified or scheduled air filter media at maximum filter face velocity of 450 feet per minute.
- B. Refer to Drawings and coordinate filter types with Section 23 40 00 - Air Filters and Cleaners.
- C. Provide filter gauges. Refer to Section 23 05 19 - Meters, Gauges and Thermometers.

2.07 HUMIDIFIER SECTION

- A. Factory install the humidifier dispersion manifold. Provide mounting channels and blank-offs as required per the manufacturer's installation requirements and to prevent air bypass.
- B. Provide humidifier with Type 304 stainless steel drain pan sloped to drain.
- C. Extend humidifier supply header to exterior of unit. Provide flanged connection. Seal air and water tight penetrations through the unit casing.
- D. Pipe humidifier header and tube drains to exterior of unit.
- E. All humidifier piping shall be stainless steel per requirements of Section 23 21 13 - Piping and Accessories.

F. Refer to the drawings and Section 15770 – Humidifiers.

2.08 VIBRATION ISOLATION AND SEISMIC RESTRAINTS

A. Refer to Drawings and Specification Section 23 05 48 - Vibration Isolation and Seismic Restraints. Provide seismic calculations for internally isolated fans.

2.09 DAMPERS

A. Provide supply, return, and outside air modulating dampers, as required. Dampers shall be heavy-duty construction aluminum construction for industrial application. The frame and blade shall be extruded aluminum. Blade end seals shall be stainless steel. Neoprene edge seals shall be installed on each blade. Blade seals shall be locked in extruded blade slots without the use of adhesives. Drive shafts shall be hexagonal to ensure proper alignment and positive locking connection between the blade, axle and linkage. Dampers shall be tested by an independent AMCA approved laboratory for leakage and air pressure drop in accordance with AMCA Standard 500 and be AMCA Certified. Leakage shall not exceed 3 cubic feet per minute per square foot at 1-inch water gauge. Pressure drop shall not exceed 0.1-inch water gauge. Dampers shall be rated for a velocity of 4,000 feet per minute without generating objectionable noise. Dampers shall be sized for a maximum velocity through the damper of 1,500 feet per minute. Coordinate damper torque requirements and actuator mounting requirements with the BMS contractor.

B. Provide backdraft dampers as shown on Drawings. Refer to Section 23 33 13 - Dampers.

2.10 LOUVERS

A. Outside air louvers shall be stationary blade type entirely contained within a 6-inch frame. Framing and blades shall be 16-gauge aluminum. A ½-inch aluminum bird-screen shall be provided on all louvers. Louvers shall be tested by an independent laboratory for water carry-over and air pressure drop in accordance with AMCA Standard 500. Intake louvers shall be sized for an intake velocity maximum of 1,000 feet per minute through the free area.

B. Exhaust Air Louvers: Louvers shall be aluminum stationary blade type entirely contained within a 6-inch frame. Framing shall be 16-gauge galvanized steel channel with box flanges. Louver blades shall be fabricated from 16-gauge aluminum. A ½-inch aluminum bird-screen shall be provided on all louvers. Louvers shall be tested by an independent laboratory for water carry-over and air pressure drop in accordance with AMCA Standard 500. Exhaust louvers shall be sized for an discharge velocity maximum of 1,300 feet per minute through the free area.

2.11 INTAKE AND EXHAUST HOODS

A. Hoods shall match casing exterior construction. Provide ½-inch aluminum bird-screen. Provide rain gutter with drain connection around hood perimeter.

B. Size hoods for intake velocity maximum of 1,000 feet per minute and exhaust discharge velocity maximum of 1,300 feet per minute.

2.12 ACOUSTICAL PERFORMANCE

A. The sound power level at the air handling unit discharge, return air inlet, fresh air inlet and/or casing radiated shall not exceed the values given in the schedule below, when operating at the maximum design airflow and static pressure conditions.

| AHU-? |
|---|
| Maximum Octave Band Sound Power Level, dB RE 10E-12 watts |

| Octave Bands Center Freq. (Hz) | 63 | 125 | 250 | 500 | 1K | 2K | 4K | 8K |
|---|-----------|------------|------------|------------|-----------|-----------|-----------|-----------|
| Unit Return | | | | | | | | |
| Unit Outlet | | | | | | | | |
| Casing Radiated | | | | | | | | |

- B. All sound power level measurements and calculations shall be in complete accordance with the latest (at time of bid) version of AMCA standard 300, Test Code for Sound Rating, AMCA standard 301, Method for Calculating Fan Sound Ratings from Laboratory Test Data. Test and calculation procedures based on sound intensity measurements may be substituted for the above procedures, if approved in advance by the Owner's Representative.
- C. The submitted sound power level shall be verified through actual measurements and calculations in accordance with AMCA standards 300 and 301 test procedures or the sound intensity technique for a minimum of 2 units, to be chosen by the Owner's Representative. These measurements will be conducted in the presence of an independent acoustical consultant who shall certify that the measurement have been conducted in accordance with the required procedure. The cost of testing and certification by the acoustical consultant shall be borne by the manufacturer.

2.13 ELECTRICAL

- A. Electrical equipment, devices, and connections shall be as specified in Division 26.
- B. Manufacturer shall supply a single point 480 volt, 3-phase power connection for the unit. Provide motor control including necessary terminal blocks, variable speed drives, contactors, motor overload protection, grounding lugs, auxiliary contacts and terminals for connection of external control devices or relays for BMS and fire alarm control. Each fan circuit shall be individually fused. Motor wiring shall be in EMT (when concealed) or liquid tight flexible steel conduit (if exposed) with a three foot section of weatherproof liquid tight flexible steel conduit to the motor to provide a vibration loop.
- C. Provide a self contained, horsepower rated, quick-make, quick-break dead front type disconnect switch for each fan motor. Interrupting rating shall be 200,000 RMS symmetrical amperes.
- D. Manufacturer shall supply a separate single point 120 volt single phase power connection for the unit lighting, switches, convenience outlets and controls. Provide an electric panel in the unit with dedicated circuit breakers for each type of device. Panel shall meet UL and NEMA requirements for the location installed.
- E. Provide 32 watt compact fluorescent vapor proof 120 volt light fixtures, steel guard, and lamp inside each access section and wired to an external weatherproof switch on the unit. Provide 120 volt, 15 amp, GFCI service receptacles with a weatherproof cover.
- F. Label and number code wiring and electrical devices in accordance with unit wiring diagram.
- G. Power wiring shall meet NEC requirements and be in EMT conduit with liquid tight flexible steel connections. Provide gasketed junction boxes.
- H. Provide an interlocking mechanism on each fan section access door to de-energize the fan where unhooded plenum fans are used. Switch shall meet OSHA, ETL and UL 1995 requirements.

2.14 CONTROLS

- A. Control Panel and Factory Mounted HVAC Controls:

1. The main control panel and integral disconnect switch shall be provided to the manufacturer by the Controls Contractor and mounted in a weatherproof service enclosure. Air handling unit shall be complete with all safety and operating controls and sensors factory installed and wired except for remote mounted components, which shall be field installed by the contractor. The main control panel shall include the following:
 - a. A 24-volt control transformer and 24-volt field wiring control terminal strip. Terminals shall be numbered for field connection of all controls in accordance with the wiring diagram.
 - b. Unit power and control wiring diagrams laminated to the door of the control panel.
- B. Other Controls:
 1. Unit shall have manual reset ionization type smoke detectors factory mounted and wired in the supply and return openings to the unit. Upon detection of smoke, fans must stop and a signal shall be sent to the building fire alarm system. Installing contractor shall coordinate this interlock with the building systems.
 2. Unit shall have terminal strips and interlocking relays factory mounted and wired to interlock with other components of the building. It is the responsibility of the contractor and the manufacturer to coordinate requirements for any additional interlocks required. Refer to Sections 23 09 00 and 23 09 93.
- C. All control wiring shall be installed without splices across casing sections (i.e., provide adequate wiring length as needed for final installation in field after unit assembly).

PART 3 – EXECUTION

- 3.01 Provide flexible connection between fans and unit casings or external duct connections if fan discharge is at the casing wall. Support connecting ductwork independent of the air handling unit. Refer to Section 23 31 00 - Ductwork.
- 3.02 Provide air tight grommets for all casing penetrations such as gage probe connections, electrical conduit for power and control wiring, control air tubing, grease tubing, etc. Extend all such connections from inside the air-handling unit to an accessible location.
- 3.03 Pipe condensate drains, inlet section drain if shown, humidifier pan drain, and humidifier drains to roof receptor. Provide stainless steel piping for humidifier drains and drain pans. Provide traps as indicated on drawing details.
- 3.04 LEAK TESTING
 - A. The Owner's Representative shall select one unit for leak testing after unit fabrication. The unit shall be tested for conformance with the leakage requirements specified above. If the unit tested does not meet specifications, all units shall be tested. The cost of testing shall be borne by the contractor.
 - B. Leak testing shall be performed by measuring the airflow pumped into (or out of) the unit at the cabinet design operating static pressure. All supply and return air openings shall be sealed along with the air seal at the supply fan to isolate the high and low side of the unit. The air shall then be pumped into (or out of) the unit until the specified leakage rating pressures are achieved. Airflow measurements shall be performed in compliance with AMCA Standard 210. A detailed report, including all data and test methods, shall be submitted.

END OF SECTION

SECTION 23 81 23

COMPUTER ROOM AIR CONDITIONING UNITS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following floor-mounted or ceiling-mounted computer room air conditioning systems:
 - 1. Chilled water computer room air conditioning systems
- B. The system shall be designed to maintain temperature and humidity conditions in the rooms containing electronic equipment.

1.02 RELATED DOCUMENTS

- A. Section 23 05 01 - Mechanical General Provisions
- B. Section 23 05 13 - Electric Motors
- C. Section 23 05 29 - Supports, Hangers, Anchors and Sleeves
- D. Section 23 05 48 - Vibration Isolation and Seismic Restraints
- E. Section 23 05 93 - Mechanical Systems Balancing
- F. Section 23 07 00 - Insulation
- G. Section 23 09 00 - Building Management System (BMS)
- H. Section 23 21 13 - Piping and Accessories
- I. Section 23 33 19 - Acoustics
- J. Section 23 34 00 - Fans
- K. Section 23 40 00 - Air Filters and Cleaners
- L. Section 23 82 16 - Hydronic Cooling and Heating Coils
- M. Section 23 82 17 - Electric Heating Coils

1.03 SUBMITTALS

- A. Product Data:
 - 1. Operating characteristics, furnished specialties, and accessories.
 - 2. Indicate published rated capacity.
 - 3. Actual net sensible cooling capacity for all AC units furnished with specified components, under scheduled conditions and in the configuration(s) shown on the drawings.

- B. Shop Drawings:
 1. Details of equipment assemblies indicating dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 2. Wiring diagrams: Power, signal, and control wiring including detailed wiring diagrams that clearly differentiate between manufacturer-installed and field-installed wiring.
 3. Dimensioned outline drawings of equipment: Identify center of gravity and locate and describe mounting and anchorage provisions.
 4. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
 5. Field quality-control test reports.
- C. Operation and Maintenance Data: For computer-room air-conditioning units to include in emergency, operation, and maintenance manuals.
- D. Warranties: Special warranties specified in this Section.

1.04 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- ~~B. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Code for Mechanical Refrigeration".~~
- ~~C. Coefficient of performance and energy efficiency ratio: Equal to or greater than prescribed by ASHRAE/IESNA 90.1, "Energy Efficient Design of New Buildings except Low-Rise Residential Buildings".~~
- ~~D. ASME Compliance: Fabricate and label water-cooled condenser shell to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels", Division 1.~~
- ~~E. Rate air-cooled condensing units up to 135,000 BTU per hour according to ARI 210/240. Rate condensing units 135,001 BTU per hour and over according to ARI 340/360.~~
- ~~F. Air-cooled condensing units factory test sound-power-level ratings shall be according to ARI 270.~~
- B. System shall be supplied with ETL and NRTL listing according to UL 1995. The specified system shall be factory-tested before shipment. Testing shall include, but shall not be limited to: Quality Control Checks, "Hi-Pot" Test (two times rated voltage plus 1000 volts, per NRTL agency requirements), and Metering Calibration Tests.

1.05 COORDINATION

- A. Coordinate layout and installation of computer-room air-conditioning units and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.
- B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in other Divisions of the specifications.
- C. Coordinate size and location of concrete housekeeping bases, cast anchor-bolt inserts into

pad, concrete, reinforcement, and formwork requirements are specified in other Divisions.

- D. Coordinate locations for refrigerant piping and electrical rough-ins.

1.06 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of computer-room air-conditioning units that fail in materials or workmanship within specified warranty period.
- B. Warranty Period for Compressors: Manufacturer's standard, but not less than ~~{five}~~~~{ten}~~ years from date of Substantial Completion.
- C. Warranty Period for Humidifiers: Manufacturer's standard, but not less than ~~{three}~~~~{Insert number}~~ years from date of Substantial Completion.
- D. Warranty Period for Electronic Control Boards: Manufacturer's standard, but not less than ~~{three}~~~~{Insert number}~~ years from date of Substantial Completion.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Computer Room Air Conditioning Systems: Stulz, ATS, Liebert
- B. Air-Cooled Condensers: Larkin, Carrier, Dunham-Bush, McQuay, Ruud, Rheem, Trane, York, Liebert

2.02 GENERAL

- A. The environmental control system shall be a factory-assembled unit. ~~On direct expansion models, the refrigeration system shall be split, with the compressor located in a remote or close-coupled condensing unit.~~
- ~~B. The evaporator section shall be designed for above-dropped-ceiling installation. Condensing units shall be designed for either outdoor or above-dropped-ceiling installation.~~
- B. Evaporator Cabinet Construction: The cabinet and chassis shall be constructed of heavy gauge galvanized steel, and shall be serviceable from one side. Mounting brackets shall be factory attached to the cabinet.
- C. Provide packaged, factory assembled, prewired, and prepiped computer room air conditioning unit (AC unit), as shown on the Drawings to operate on 460 ~~{208}~~~~{230}~~ volt, 3-phase, 60 Hz power.
- D. Air Distribution: The fan shall be the centrifugal type, double width, double inlet. The shaft shall be heavy-duty steel with self-aligning ball bearings with minimum life of 100,000 hours. The fan motor shall be 1750 rpm and mounted on an adjustable base. The drive package shall be equipped with an adjustable motor pulley. The fan/motor assembly shall be mounted on vibration isolators.
- E. System shall be suitable for ducted air distribution.
- F. Microprocessor Control: The control system shall be microprocessor based. The wall-mounted control enclosure shall include a 2-line by 16-character LCD display providing continuous display of operating status and alarm condition. A 7-key keypad for setpoint/program control and AC unit on/off shall be located below the display.

- G. Temperature and humidity sensors shall be located in a wallbox, which shall be capable of being located up to 300 feet from the evaporator unit.
- H. Monitoring: The LCD display shall provide on/off indication, operating mode indication (cooling, heating, humidifying, dehumidifying) and current day, time, temperature and humidity (if applicable) indication. The monitoring system shall be capable of relaying AC unit operating parameters and alarms to a generic monitoring system.

2.03 CONTROL SETPOINT PARAMETERS

- A. Temperature setpoint 65 degrees – 85 degrees F
- B. Temperature sensitivity 1 degree – 5 degrees F
- C. Humidity setpoint 20 percent – 80 percent relative humidity
- D. Humidity sensitivity 1 percent – 10 percent relative humidity

2.04 AC UNIT CONTROLS

- ~~A. Compressor Short-Cycle Control: The control system shall prevent compressor short cycling by a 3-minute timer from compressor stop to the next start.~~
- A. Common Alarm and Remote On/Off: A common alarm relay shall be provided to provide a contact closure to a remote alarm device. Two (2) terminals shall also be provided for remote on/off control. Individual alarms shall be “enabled” or “disabled” from reporting to the common alarm.
- B. Setback Control: The control shall be programmable on a daily basis or on a 5-day/2 day program schedule. It shall be capable of accepting 2 programs per day.
- C. Temperature Calibration: The control shall include the capabilities to calibrate the temperature and humidity sensors and adjust the sensor response delay time from 1 to 90 seconds. The control shall be capable of displaying temperature values in degrees F or C.
- D. System Auto Restart: For start-up after power failure, the system shall provide automatic restart with a programmable (up to 9.9 minutes in 6-second increments) time delay. Programming can be performed either at the wall-mounted controller or from the central site monitoring system.

2.05 ALARMS

- A. AC Unit Alarm: The control system shall monitor AC unit operation and activate an audible and visual alarm in the event of the following factory preset alarm conditions:
 - 1. High and low temperature
 - ~~2. High and low humidity~~
 - ~~3. High head pressure~~
 - 2. Change filter
 - 3. Loss of air
 - 4. Local alarm
- B. Custom Alarms:
 - 1. Humidifier problem
 - 2. Water detected
 - 3. Smoke detected
 - 4. User customized text can be entered for the two (2) custom alarms

- C. Alarm Controls: Each alarm (~~AC unit and custom~~) shall be separately enabled or disabled, selected to activate the common alarm (except for high head pressure).
- D. Audible Alarm: The audible alarm shall annunciate any alarm that is enabled by the operator.
- E. Common Alarm: A programmable common alarm shall be provided to interface user selected alarms with a remote alarm device.
- F. Remote Monitoring: All alarms shall be communicated to the generic remote monitoring system with the following information: date and time of occurrence, AC unit number, and present temperature and humidity.

2.06 CHILLED WATER SYSTEM COMPONENTS

- ~~A. Chilled Water Control Valve (On/Off): The [2-way] [3-way] control valve shall be motorized slow-acting type to reduce water hammer. Design pressure shall be [150] [300] psig, with a maximum close-off pressure of 75 psi.~~
- A. Chilled Water Control Valve (Modulating): A 2-way ~~[2-way]~~ **[3-way]** modulating valve controlled by the microprocessor to position the valve in response to room conditions. Design pressure shall be ~~[150] [300]~~ psig, with a maximum close-off pressure of 75 psi.
- B. Chilled Water Coil: The cooling coil shall be 4 rows deep, constructed of copper tubes and aluminum fins and has a maximum face velocity of 500 feet per minute.
- C. The coil assembly shall be mounted in a stainless steel condensate drain pan, with internally trapped drain line. The evaporator drain pan shall include a factory installed float switch to shutdown the evaporator upon high water condition.

2.07 FACTORY INSTALLED OPTIONS

- A. Disconnect Switch, Non-Locking: The non-automatic, non-locking, molded case circuit breaker shall be factory mounted in the high voltage section of the electrical panel. The switch shall be accessible from the front of the AC unit.
- B. Firestat: The firestat shall immediately shut down the system when high temperatures are detected. The firestat shall be mounted with the sensing element in the return air.
- C. Smoke Detector: The smoke detector shall immediately shut down the environmental control system and activate the alarm system when activated. The sensing element shall be located in the return air compartment.
- D. Remote Sensors: The AC unit shall be supplied with remote temperature and humidity sensors. The sensors shall be connected to the AC unit by a shielded cable.
- E. Air Filter Box: The evaporator section shall be supplied with an air filter box for use with ducted installations. Two (2) filters shall be included 4 x 20 x 20 inches each, pleated type, with a minimum efficiency of 40 percent, based on ASHRAE 52.1.
- F. Condensate Pump: The condensate pump shall be complete with integral float switch, pump, motor assembly, and reservoir.
- G. Refrigerant Line Sweat Adapter Kit: Provide a sweat adapter kit to permit field brazing of refrigerant line connections.
- H. The filter clog switch shall activate the audible and visual alarm on the wallbox when filter pressure drop exceeds and adjustable setpoint.

- I. Single Point Power Kit: A single point power kit shall be provided for a close-coupled system to allow a single electrical power feed to supply power to both the evaporator and indoor close-coupled condensing unit.
- J. Remote Monitoring System: Provided remote monitoring of the AC unit and monitoring of other support equipment. The remote monitoring shall have the capability to monitor and change (at the user direction) the temperature and humidity setpoints and sensitivities of each AC unit. The printer shall provide the user with chronological alarm information. It shall also be capable of being programmed to print out environmental conditions or operating modes at each AC unit.

~~2.08 DRYCOOLER~~

~~A. ELECTRICAL CONTROLS~~

- ~~1. All electrical connections shall be provided in a weatherproof enclosure.~~
- ~~2. The enclosure shall be integral with the condenser for pleasing appearance as well as functional protection. A door mounted and internally wired electrical disconnect switch shall be included on all models with integral pump controls and optional on other models.~~
- ~~3. Provide magnetic contactor and control voltage for remote starting of the drycooler.~~
- ~~4. Fan cycling shall be used to control leaving fluid temperature by cycling fans in one or two steps. The 24 volt control circuit furnished, consists of control transformer, fan contactors and temperature controls as specified.~~

- ~~B. Fan cycling with pump control shall be as specified for the fan cycling model, plus starters for the pumps and a built-in disconnect switch. Dual pump control shall also include a manual pump lead/lag switch and automatic controls to switch to the standby in the event of failure of the primary pump. A flow switch, shipped with the dual pump package, shall initiate switchover.~~

PART 3 – EXECUTION

3.01 INSTALLATION OF AIR CONDITIONING UNIT

- A. General: Install air conditioning unit in accordance with manufacturer's installation instructions. Install AC unit plumb and level, firmly anchored to support the AC unit weights in location indicated, and maintain manufacturer's recommended clearances.
- B. Electrical Wiring: Install and connect electrical devices furnished by manufacturer but not specified to be factory mounted. Furnish copy of manufacturer's electrical connection diagram submittal to electrical contractor.
- C. Piping Connections: Install and connect devices furnished by manufacturer but not specified to be factory mounted. Furnish copy of manufacturer's piping connection diagram submittal to piping contractor.
- D. Supply and Drain Water Piping: Connect water supply and drains to air conditioning unit. AC unit drain shall be trapped internally, and shall not be trapped externally.
- E. Field Quality Control: Start up air conditioning unit in accordance with manufacturer's start up instructions. Test controls and demonstrate compliance with requirements.

END OF SECTION

SECTION 23 05 01

MECHANICAL GENERAL PROVISIONS

PART 1 – GENERAL

1.01 DESCRIPTION

- A. The General and Supplementary Conditions and Division 1 are a part of the requirements for the work under this Division of the Specification.

1.02 WORK INCLUDED

- A. Provide labor and materials required to install, test and place into operation the heating, ventilating, and air conditioning, ~~plumbing and fire protection~~ systems as called for in the Contract Documents and according to applicable codes and regulations.
- B. Provide labor, materials and accessories required to provide complete operating mechanical systems as described or which may be reasonably implied as essential for a complete operating system.

1.03 QUALITY ASSURANCE

- A. Comply with current governing codes, ordinances and regulations of the authority or authorities having jurisdiction over any part of the work and secure all necessary permits. Comply with the regulations and requirements of the Owner's insurance underwriter.
- B. Where codes or standards are referenced, the applicable portions apply.
- C. Drawings, specifications, codes and standards are minimum requirements. Where requirements differ, apply the more stringent.
- D. Should any change in drawings or specifications be required to comply with governing regulations, notify the Architect prior to submitting bid.
- E. Execute work in strict accordance with the best practices of the trades in a thorough, substantial, skillful and well-executed manner by competent workers. Provide a competent, experienced full-time Superintendent who is authorized to make decisions on behalf of the Contractor.
- F. The Architect or Architect's Representative may conduct unannounced field reviews of any work completed or in progress during the Contractor's working hours. A report will be issued to the Contractor if the field review of the mechanical, plumbing and fire protection systems construction has revealed elements of the work, which are inconsistent with the Contract Documents. All items in the report shall be addressed in writing by the Contractor within two (2) weeks and corrections in the field shall be made as directed.

1.04 ABBREVIATIONS AND DEFINITIONS

A. Abbreviations:

- | | | |
|----|-------|---|
| 1. | AABC | American Association of Balancing Contractors |
| 2. | ABMA | American Boiler Manufacturers Association |
| 3. | ADC | Air Diffusion Council |
| 4. | AFBMA | Anti-Friction Bearing Manufacturers Association |
| 5. | AGA | American Gas Association |
| 6. | AMCA | Air Movement and Control Association |
| 7. | ANSI | American National Standards Institute |

| | | |
|-----|--------|--|
| 8. | ARI | Air Conditioning and Refrigeration Institute |
| 9. | ASA | Acoustical Society of America |
| 10. | ASHRAE | American Society of Heating, Refrigeration, and Air Conditioning Engineers |
| 11. | ASME | American Society of Mechanical Engineers |
| 12. | ASTM | American Society for Testing and Materials |
| 13. | AWWA | American Water Works Association |
| 14. | CTI | Cooling Tower Institute |
| 15. | EPA | Environmental Protection Agency |
| 16. | FM | Factory Mutual |
| 17. | IEEE | Institute of Electrical and Electronic Engineers |
| 18. | NEBB | National Environmental Balancing Bureau |
| 19. | NEMA | National Electrical Manufacturers Association |
| 20. | NFPA | National Fire Protection Association |
| 21. | OSHA | Occupational Safety and Health Administration |
| 22. | SAE | Society of Automotive Engineers |
| 23. | SMACNA | Sheet Metal and Air Conditioning Contractors National Association |
| 24. | UL | Underwriters Laboratories |

1.05 GUARANTEE

- A. Submit a single guarantee stating that the work is in accordance with Contract Documents. Guarantee work against faulty and improper material, fabrication, installation, start-up and commissioning for a period of one (1) year from date of final acceptance by the Owner, except that where guarantees or warranties for longer terms are specified herein, the longer term shall apply. Correct any deficiencies, which occur during the guarantee period, within 24 hours of notification, at no additional cost to the Owner, to the satisfaction of the Owner. Obtain similar guarantees from subcontractors, manufacturers, suppliers and sub-trade specialists.

1.06 USE OF THE ARCHITECT'S AND ENGINEER'S DRAWINGS

- A. The Contractor shall obtain, at the Contractor's expense, from the Architect or Engineer a set of AutoCAD or compatible format architectural and engineering drawings on electronic media where desired by the Contractor and/or required by the Specifications for use in preparing the shop drawings, coordination drawings, and record drawings. The Contractor shall provide to the Architect and Engineer a written release of liability acceptable to the Architect and Engineer prior to receiving the electronic media files.

PART 2 – PRODUCTS

2.01 EQUIPMENT AND MATERIALS

- A. Provide products and materials that are new, clean, free of defects and free of damage and corrosion.
- B. Products and materials shall not contain asbestos, PCBs or any other material that is considered hazardous by the Environmental Protection Agency or any other authority having jurisdiction.
- C. Replace materials of less than specified quality and relocate work incorrectly installed as directed by the Architect.
- D. Statically and dynamically balance rotating equipment for minimum vibration and lowest operating noise level.
- E. Provide name/data plates on major components of equipment with manufacturer's name,

model number, serial number, capacity data and electrical characteristics attached in a conspicuous place.

- F. Install materials and equipment with qualified trades people.
- G. Maintain uniformity of manufacture for equipment used in similar applications and sizes.
- H. Applicable equipment and materials to be listed by Underwriters Laboratories and manufactured in accordance with ASME, AWWA, or ANSI standards, and as approved by authorities having jurisdiction. The energy-using products shall be certified for use in State of California and meet State energy efficient standards.
- I. Fully lubricate equipment when installed.
- J. Do not operate air systems until ductwork is complete, temporary filters are in place and construction debris is removed. Provide 1-inch thick fiberglass filter media across the face of each return air opening prior to start of each air system during temporary system operation and system clean-out.
- K. Do not operate water or steam systems until piping has been cleaned and startup strainers are in place.
- L. Install floor mounted equipment on a 4-inch high concrete pad. Concrete work shall be provided by another trade. Coordinate size and location with actual equipment used and accepted layout shop drawings.
- M. Secure equipment with bolts, washers and locknuts of ample size to support equipment. Embedded anchor bolts to have bottom plate and pipe sleeves. Grout machinery set in concrete under entire bearing surface. After grout has set, remove wedges, shims and jack bolts and fill space with grout.
- N. Locate valves, traps, damper operators, dielectric unions, access doors, etc., to be easily accessible, either in mechanical spaces or through access panels specified. Obtain Architect's approval of access panel locations.
- O. Follow manufacturers' recommendations and instructions for installing, connecting, and adjusting equipment. Provide a copy of such instructions at the equipment during installation.
- P. Pressure vessels and relief valves shall be selected, built and labeled in accordance with ASME.
- Q. Equipment capabilities, etc., are scheduled or specified for job site operating conditions. Equipment sensitive to altitude shall be derated with the method of derating identified on shop drawings.

2.02 ALTERNATIVE EQUIPMENT AND MATERIALS

- A. Contract Documents are based on materials specified and on equipment manufacturers indicated. Acceptance of alternative equipment manufacturers does not relieve Contractor of the responsibility to provide equipment and materials, which meet the quality and performance as stated or implied in the Contract Documents.
- B. Equipment manufacturers listed in individual sections are acceptable for this project, subject to requirements of contract documents.
- C. Submit proposals to supply alternate materials or equipment, in writing, with sufficient lead time for review prior to the date equipment must be ordered to maintain project schedule. Reimburse Owner for costs associated with the review of the proposed alternative whether

alternative is accepted or rejected.

- D. Include revisions required to adapt alternatives in such proposals, including revisions by other trades. No increase in the contract price will be considered to accommodate the use of alternative equipment.
- E. Wherever quality standards (such as serviceability, energy efficiency, longevity or durability), operating results (such as noise levels, quantity delivered or pressure obtained) are specified or scheduled, or when the manufacturer and size of equipment, for which such operating results are published or determinable, is specified, the substitution being proposed must conform substantially to the quality and quantities specified or implied. The substitution must fit into available space conditions and must function properly in coordination with the rest of the system.
- F. Proposed changes and substitutions of systems, equipment and manufacturers shall be submitted and include the following information with the proposal:
 - 1. A description of the difference between the existing contract requirements and that proposed, the comparative features of each, and the effect of the change on the end result performance. Include the impact of all changes on other contractors and acknowledge the inclusion of additional costs to other trades.
 - 2. Schematic drawings and details to supplement the description.
 - 3. A list of the contract requirements that must be revised if the change is accepted, including any specification revisions.
 - 4. Complete list of materials and equipment proposed for use in the change.
 - 5. Include a description and estimate of costs the Owner may incur in implementing the change, such as additional space requirements, permits, architectural and aesthetic impact, design costs, tests, permits evaluation, operating and support costs.
 - 6. A projection of any effects the proposed change would have on collateral costs to the Owner.
 - 7. A statement of the time by which a contract modification accepting the change must be issued, noting any effect on the contract completion time or the delivery schedule.
 - 8. A statement indicating the reduction to the contract price if the Owner accepts the change. Be responsible for appropriate modifications to all trades.

PART 3 – EXECUTION

3.01 FEES

- A. Pay all required fees and obtain required permits related to the mechanical installation.
- B. Pay royalties or fees in connection with the use of patented devices and systems.
- C. Provide controlled or witnessed inspection where required by authorities having jurisdiction or by these specifications.

3.02 SUBMITTALS AND REVIEWS

- A. Submit shop drawings, manufacturer's data, samples and test reports as specified.
- B. Within two (2) months after notice to proceed by the Owner or Owner's Representative, or after execution of Owner/Contractor Agreement, submit a complete typed list of all mechanical equipment manufacturers and material suppliers for the equipment proposed to be provided on this project as well as names of all subcontractors.
- C. Within three (3) months after notice to proceed by the Owner or Owner's Representative or after execution of Owner/Contractor Agreement, prepare an index of all submittals for the project. Include a submittal identification number, a cross-reference to the specification

sections or drawing number, and an item description. Prefix the submittal identification number by the specification sections to which they apply. Indicate on each submittal, the submittal identification number in addition to the other data specified. All subcontractors shall utilize the assigned submittal identification number.

- D. After the Contract is awarded, obtain complete shop drawings, product data and samples from the manufacturers, suppliers, vendors, and all subcontractors, for all materials and equipment as specified. Submit data and details of such materials and equipment for review. Prior to submission certify that the shop drawings, product data and samples are in compliance with the Contract Documents. Check all materials and equipment upon their arrival on the job site and verify their compliance with the Contract Documents. Modify any work, which proceeds prior to receiving accepted shop drawings as required to comply with the Contract Documents and the shop drawings.
- E. Review of submittals is for general compliance with the design concept and Contract Documents. Comments or absence of comments does not relieve the Contractor from compliance with the Contract Documents. The Contractor remains solely responsible for details and accuracy, for confirming and correlating all quantities and dimensions, for selecting fabrication processes, for techniques of construction, for performing the work in a safe manner, and for coordinating the work with that of other trades.
- F. No part of the work shall be ordered, procured, started in the shop or in the field until the shop drawings and samples for that portion of the work have been submitted, reviewed and returned with either "No Exceptions Noted" or "Exceptions Noted" marked on the submission.
- G. A minimum period of ten (10) working days, exclusive of transmittal time, will be required in the Architect/Engineer's office each time a shop drawing, product data and/or samples are submitted for review. This time period must be considered by the Contractor in the scheduling of the work.
- H. Submit one (1) transparency and two (2) bond prints of all items requiring shop drawings. Submit three (3) copies of manufacturer's product submittals. One (1) transparency and one (1) bond print or two (2) copies of submittals will be returned. Additional copies are the responsibility of the Contractor. Electronic media will not be reviewed.

I. Submissions will be stamped as follows:

| Stamp | Interpretation |
|--|--|
| No Exceptions Noted | Fabrication, manufacture, or construction may proceed providing submittal complies with the Contract Documents. |
| Exceptions Noted: <input type="checkbox"/> Resubmit for Record <input type="checkbox"/> No Resubmission Required | Fabrication, manufacture, or construction may proceed providing submittal complies with the Contract Documents and Engineer's notations are complied with. Within this category are two options. A resubmission for our records is required when corrections are necessary. A resubmission is not required if there are only minor comments. |
| Revise and Resubmit | The submittal does not comply with the Contract Documents; do not proceed with fabrication, manufacture, or construction. The work and shop drawings are not permitted at the job site. Resubmit appropriate shop drawings. |

- J. Submit materials and equipment by manufacturer, trade name and model number. Include clear, legible copies of applicable brochure or catalog material. Maintenance and operating manuals are not suitable substitutes for shop drawings.
- K. Identify each sheet of printed submittal pages (using arrows, underlining or circling) to show applicable sizes, types, model numbers, ratings, capacities and options actually being proposed. Cross out non-applicable information. Note specified features such as voltages, motor efficiencies, special tank linings, pump seals, materials or paint finishes. Cross out all references to "options". Cross out statements such as "subject to change without notice" or "not for construction". Anything not specifically excluded is assumed to be included.
- L. Include dimensional data for roughing in and installation, technical data sufficient to verify that equipment meets requirements of the Contract Documents. Include wiring, piping and service connection data, motor sizes complete with voltage ratings and schedules.
- M. Maintain a complete set of the most current reviewed and stamped shop drawings and product data on site.
- N. Prepare and submit detailed shop drawings for ductwork, piping work and other distribution services in minimum ¼-inch = 1-foot scale, including elevations and locations and sizes of openings in floor decks, walls and roofs.
- O. The work described in shop drawing and product data submittals shall be carefully checked by all trades for clearances (including those required for code compliance, maintenance and servicing), field conditions, maintenance of architectural conditions and proper coordination with other trades on the job. Each submitted shop drawing to include a certification that related field conditions and requirements have been checked by all Contractors and Subcontractors and that conflicts do not exist.
- P. The Contractor is not relieved of the responsibility for dimensions or errors that may be contained on submissions or for deviations from requirements in the Contract Documents. The noting of some errors but overlooking others does not grant the Contractor permission to proceed in error. Regardless of any information contained in the shop drawings, product data and samples, the Contract Documents govern the work and are neither waived nor superseded in any way by the review of shop drawings, product data and samples.
- Q. Inadequate or incomplete shop drawings, product data and/or samples will not be reviewed

and will be returned to the Contractor for resubmittal.

- R. Indicate the following in the lower right hand corner of each shop drawing, and on the front cover of each product data brochure: the submittal identification number; title of the sheet or brochure; name and location of the Project; names of the Architect, Engineer, Contractor, Subcontractor, Manufacturer, Supplier, and Vendor; the date of submittal; and the date of each correction, version and revision. Number all pages and drawings in product data brochures, test reports or submittals consecutively from beginning to end. Unless the above information is included, the submittal will be returned for resubmission. Resubmittals of shop drawings or product data or brochures shall include a cover letter summarizing the corrections made in response to the review comments.

3.03 COORDINATION OF WORK

- A. The Contract Documents establish scope, materials and quality but are not detailed installation instructions. Drawings are diagrammatic.
- B. The Contract Documents show the general arrangement of equipment, ductwork, piping and accessories. Follow these drawings as closely as the actual construction and the work of other trades will permit. Provide offsets, fittings, and accessories, which may be required but not shown on the drawings. Investigate the site and review drawings of other trades to determine conditions affecting the work and provide such work and accessories as may be required to accommodate such conditions.
- C. Certain products will be provided by other trades. Examine the Contract Documents to ascertain the requirements for installation of these products.
- D. Carefully check space requirements with other trades to insure that material can be installed in the spaces allotted.
- E. Wherever work interconnects with work of other trades, coordinate with other trades to insure that they have the information necessary so that they may properly install the necessary connections and equipment. Identify items (valves, dampers, coils, etc.) requiring access in order than the ceiling and partition contractors can install access doors and panels in the correct locations.
- F. Consult with other trades regarding equipment so that, wherever possible, motors, motor controls, pumps and valves are of the same manufacturer.
- G. Furnish and set sleeves for passage of pipes, ducts and conduits through structural masonry and concrete walls, roofs and floors and elsewhere as will be required for the proper protection of each pipe and duct passing through building surfaces.
- H. Install firestopping around all pipes, conduits, etc., which pass through rated walls, partitions and floors in strict accordance with the manufacturers published approval listing and rating.
- I. Provide detailed information on openings and holes required in structural elements and precast panels or components for mechanical work.
- J. Provide required structural or architectural supports and hangers for ductwork, piping and equipment, designed so as not to exceed allowable loadings of structures.
- K. Examine and compare the Contract Drawings and Specifications with the drawings and specifications of other trades, report any discrepancies between them to the Architect and obtain written instructions for changes necessary in the work. Install and coordinate the work in cooperation with other related trades. Before installation, make proper provisions to avoid interferences.
- L. Wherever the work is of sufficient complexity, prepare additional detail drawings to scale to

coordinate the work with the work of other trades. Detailed work shall be clearly identified on the Drawings as to the area to which it applies. Submit these drawings to the Architect for review. At completion include a set of these drawings with each set of record drawings.

- M. Before commencing work, examine adjoining work on which this work is in any way dependent and report conditions that prevent performance of the work. Become thoroughly familiar with actual existing conditions to which connections must be made or which must be changed or altered.
- N. Adjust location of pipes, ducts, panels, equipment, etc., to accommodate the work to prevent interferences, both anticipated and encountered. Determine the exact route and location of each pipe and duct prior to fabrication.
 - 1. Right-of-Way: Lines which pitch have right-of-way over those which do not pitch. For example: condensate, steam, and plumbing drains normally have right-of-way. Lines whose elevations cannot be changed have right-of-way over lines whose elevations can be changed.
 - 2. Provide offsets, transitions and changes in direction of pipes and ducts as required to maintain proper head room and pitch on sloping lines. Provide traps, air vents, drains, etc., as required to effect these offsets, transitions and changes in direction.
- O. Install mechanical work to permit removal (without damage to other parts) of hydronic coils, heat exchanger, boiler or chiller tube bundles, heat exchanger plates, controls, fan shafts and wheels, smoke detectors, filters, belt guards, sheaves and drives, and any other parts requiring periodic replacement or maintenance. Arrange pipes, ducts, and equipment to permit access to valves, cocks, traps, starters, motors, and control components, and to clear the openings of swinging doors and access panels.
- P. Changes in the cross-sectional dimensions of ductwork are permissible when required to meet job conditions. Maintain at least the same equivalent cross-sectional duct area in accordance with the latest edition of the ASHRAE Guide. Secure the approval of the Architect prior to fabrication of ductwork requiring these changes.
- Q. Provide access panels in equipment, ducts, etc., as required for inspection and maintenance of concealed or internal equipment, dampers, plenums, smoke detectors, humidifiers, controls, etc.
- R. In cases of doubt as to the Work intended, or in the event of need for explanation thereof, request supplementary instructions from the Architect.

3.04 CONTRACTOR'S COORDINATION DRAWINGS

- A. The Contractor shall coordinate efforts of all trades and shall furnish (in writing, with copies to the Architect) any information necessary to permit the work of all trades to be installed satisfactorily and with the least possible interference or delay.
- B. The Contractor and all trade contractors shall prepare a complete set of construction Coordination Drawings indicating the equipment actually purchased and the exact routing for all lines such as piping, busway, conduit, ductwork, etc., including conduit embedded in concrete floors and walls. The Coordination Drawings shall be submitted complete to the Architect and the Engineer within three (3) months after notice to proceed is given and in compliance with the construction schedule for the project. The sheet metal drawings, at a scale of not less than ¼-inch to 1-foot, shall serve as the base drawings to which all other Contractors shall add their work. Each separate Trade Contractor shall draw their work on separate layers with different color assignments to facilitate coordination. Each Coordination Drawing shall be completed and signed off by the other Trade Contractors and the Contractor prior to the installation of the HVAC, plumbing, electrical and fire sprinkler work in the area covered by the specific drawing. The Contractor's work shall be installed according to the shop drawings and Coordination Drawings. If the Contractor allows one trade to install their

work before coordination with the work of other trades, the Contractor shall make all necessary changes to correct the condition at no additional cost to the Owner.

- C. The Contractor's Coordination Drawings shall indicate structural loads at support points for all piping 10-inch and larger, racked piping, racked conduit and busway. Submit to Structural Engineer for review and approval. The elevation, location, support points, static, dynamic and expansion forces and loads imposed on the structure at support and anchor points shall be indicated. All beam penetrations and slab penetrations shall be indicated and sized and shall be coordinated. Work routed underground or embedded in concrete shall be indicated by dimension to column and building lines and shall be coordinated. Coordination Drawings shall document all required structural penetrations for initial construction. Penetrations shall be dimensioned for walls, floors and roofs. These structural coordination requirements require review and approval by the Structural Engineer prior to completion and submittal of the drawings.
- D. This requirement for Coordination Drawings shall not be construed as authorization for the Contractor or trade contractors to make any unauthorized changes to the Contract Documents. Contract document space allocations shall be maintained such as ceiling height, designated clearance for future construction and flexibility, chase walls, equipment room size, unless prior written authorization is received from the Architect to change them.
- E. Prior to final acceptance of the Work, the Contractor shall submit the Coordination Drawings as part of the Record Drawing submittal.

3.05 EXAMINATION OF SITE

- A. The Contract Documents do not make representations regarding the character or extent of the subsoils, water levels, existing structural, mechanical and electrical installations, above or below ground, or other sub-surface conditions which may be encountered during the work.
- B. Evaluate existing conditions that may affect methods or cost of performing the work, based on examination of the site or other information. Failure to examine the Drawings or other information does not relieve the Contractor of responsibility for satisfactory completion of the work.

3.06 EXCAVATION AND BACKFILL

- A. Provide excavation for the work of this Division. Excavate all material encountered, to the depths indicated on the Drawings or required. Remove excavated materials not required or suitable for backfill from the site. Provide grading as may be necessary to prevent surface water from flowing into trenches or other excavations. Remove any water that accumulates. Provide sheeting and shoring as may be necessary for the protection of the work and for the safety of personnel.
- B. Provide trenches of widths necessary for the proper execution of the work. Grade bottom of the trenches accurately to provide uniform bearing and support the work on undisturbed soil at every point along its entire length. Except where rock is encountered, do not excavate below the depths indicated. Where rock excavations are required, excavate rock to a minimum overdepth of four inches below the trench depths indicated on the Drawings or required. Backfill overdepths in the rock excavation and unauthorized overdepths with loose, granular, moist earth, thoroughly machine tamped to a compaction level of at least 95 percent of standard proctor density or 75 percent relative density or as specified by the Architect. Whenever unstable soil that is incapable of properly supporting the work is encountered in the bottom of the trench, remove soil to a depth required and backfill the trench to the proper grade with coarse sand, fine gravel or other suitable material.
- C. Excavate trenches for utilities that will provide the required minimum depths of cover from existing grade or from indicated finished grade, whichever is lower, unless otherwise specifically shown.

- D. Trenches shall not be placed within ten (10) feet of foundation or soil surfaces that must resist horizontal forces.
- E. Do not backfill trenches until all required tests have been performed and the installation observed by the Architect. Comply with the requirements of other sections of the specifications. Backfill shall consist of non-expansive material with limited porosity. Deposit backfill in 6-inch thick layers and tamp carefully until the mechanical work is covered by not less than 12 inches of material. Backfill and tamp remainder of trench at 1 foot intervals until complete. Uniformly grade the finished surface.

3.07 CUTTING AND PATCHING

- A. Where cutting, channeling, or drilling of floors, walls, partitions, ceilings or other surfaces is necessary from the proper installation, support or anchorage of ductwork, piping or equipment, layout the work carefully in advance. Repair any damage to the building, piping, equipment or finishes using skilled tradesmen for all required work.
- B. Do not cut, channel or drill unfinished masonry, tile, etc. unless written permission is obtained from the Architect. Perform this work in a manner acceptable to the Architect.
- C. Where ductwork, piping or equipment are mounted on a painted finished surface, or a surface to be painted, paint to match the surface. Cold galvanize bare metal whenever support channels are cut.
- D. Provide slots, chases, openings and recesses through floors, walls, ceilings, and roofs as required. Where these openings are not provided, provide cutting and patching to accommodate penetrations at no additional cost to the Owner.

3.08 PROHIBITED LABELS AND IDENTIFICATIONS

- A. Prohibited Markings: In all public areas, tenant areas, storage areas and similar locations within the project, the inclusion or installation of any equipment, fixture or assembly which bears on any exposed surface any name, trademark, or other insignia which is intended to identify the manufacturer, the vendor, or other source(s) from which such object has been obtained, is prohibited.
- B. Exception: Required Underwriters Laboratories labels shall not be removed nor shall identification specifically required under the various technical sections of the Specifications be removed.

3.09 EQUIPMENT PAD AND ANCHOR BOLTS

- A. Provide concrete pads under all floor-mounted mechanical equipment. This includes electrical components, equipment mounted on legs and pipe support stands. Equipment pads shall conform to the shape of the piece of equipment it serves with a minimum 2-inch margin around the equipment and supports. Pads shall be a minimum of 4 inches high and made of a minimum 28-day, 2500-psi concrete reinforced with 6-inch by 6-inch 6/6-gauge welded wire mesh. Trowel tops and sides of pad to smooth finishes, equal to those of the floors, with all external corners bullnosed to a 3/4-inch radius. Use shop drawings stamped "NO EXCEPTIONS NOTED" or "EXCEPTIONS NOTED" for dimensional guidance in sizing pads.
- B. Provide galvanized anchor bolts for all equipment placed on concrete equipment pads, inertia blocks, or on concrete slabs. Verify bolts size, number and embed depth recommended by the manufacturer of the equipment with seismic calculations as specified, and locate by means of suitable templates. Equipment installed on vibration isolators shall be secured. Secure the isolator to the floor, pad, or support as recommended by the vibration isolation and seismic restraint manufacturer.

- C. Where equipment is mounted on gypsum board partitions, the mounting screws will pass through the gypsum board and be securely attached to the partition studs. As an alternative, the mounting screws may pass through the gypsum board and be securely attached to 6-inch square, 18-gauge galvanized metal backplates that are attached to the gypsum board with an approved non-flammable adhesive. Toggle bolts installed in gypsum board partitions are not acceptable.

3.10 DELIVERY, DRAYAGE AND HAULING

- A. Include all drayage, hauling, hoisting, shoring and placement in the building of equipment specified and be responsible for the timely delivery and introduction of equipment to the project as required by the construction schedule. If any item of equipment is received prior to the time it is required, be responsible for its proper storage and protection until the time it is required. Pay for all costs of demurrage or storage.
- B. If equipment is not delivered or installed at the project site in a timely manner as required by the project construction schedule, the Contractor shall be responsible for disassembly, re-assembly, manufacturer's supervision, shoring, general construction modification, delays, overtime costs, etc., at no additional cost to the Owner.

3.11 EQUIPMENT AND MATERIAL PROTECTION

- A. Protect the work equipment and material of other trades from damage by work or workers of this trade, and correct damage caused without additional cost to the Owner.
- B. The Contractor shall be responsible for all work, materials and equipment until finally inspected, tested and accepted. Protect work against theft, injury or damage; and carefully store material and equipment received on site that is not immediately installed. Close open ends of work with temporary covers or plugs during construction to prevent entry of dust, dirt, water or other obstructing material. Cover and protect equipment and materials from damage due to water, moisture, humidity, paint, spray-on fireproofing, construction debris, etc. Store equipment subject to moisture damage, such as insulation or electrical components in dry heated spaces.
- C. Provide adequate means for fully protecting finished parts of the materials and equipment against damage from whatever cause during the progress of the work until final acceptance. Protect materials and equipment in storage and during construction in such a manner that no finished surfaces will be damaged or marred, and moving parts are kept clean and dry. Do not install damaged items; take immediate steps to obtain replacement or repair. Replace all wet or damp insulation or acoustic lining.

3.12 ELECTRICAL EQUIPMENT AND ELECTRICAL ROOM PRECAUTIONS

- A. Do not install piping, equipment or ductwork for heating, ventilation, air conditioning, plumbing or any piping systems not included as part of the electrical work, in the following rooms: switchgear, transformer, generator, elevator equipment, telephone, fire command, security, dimmer or electrical equipment rooms.
- B. Do not install piping, equipment or ductwork above switchboards, disconnects, panelboards, dimmers, control panels, VFDs, motor control centers, individual motor controllers, electronics, etc or the code required service space for these electrical devices.

3.13 EQUIPMENT GUARDS

- A. Provide easily (without tools) removable expanded metal guards for all hot surfaces, belts, couplings, exposed fan inlets and outlets, and other moving parts of machinery. Provide tachometer openings in the guards at least 2 inches in diameter, for all belt-driven, gear-driven or variable speed machinery. Comply with OSHA requirements for all equipment guards.

3.14 LUBRICATION

- A. Provide means for lubricating all bearings and other machine parts. If a part requiring lubrication is concealed or inaccessible, extend a metallic lubrication tube with suitable fitting to an accessible location and identify it with permanent laminated plastic nameplates. Identify this location in the maintenance manual.
- B. After installation, properly lubricate all parts requiring lubrication and keep them adequately lubricated with a lubricant recommended by the equipment manufacturer until Owner acceptance.

3.15 DATE OF COMPLETION AND TESTING OF MECHANICAL SYSTEMS

- A. Comply with the project construction schedule for the date of final performance and acceptance testing, and complete work sufficiently in advance of the Contract completion date to permit the execution of the testing prior to occupancy and the Contract closeout. Complete any adjustments and/or alterations that the final acceptance tests indicate as necessary for the proper functioning of all equipment prior to the completion date. See individual sections for extent of testing required.
- B. Provide a detailed schedule of completion indicating when each system is to be completed and outlining when tests will be performed. Submit completion schedule for review within three (3) months after the notice to proceed by Owner or Owner's Representative has been given. Update this schedule periodically as the project progresses.

3.16 OPERATING INSTRUCTIONS AND OPERATOR TRAINING

- A. Provide the services of factory trained specialists to supervise the operation of all equipment and systems specified and train the Owner's operating and maintenance personnel for a ten (10) day operating/instruction period. Operating instruction time is defined as straight time working hours and not including nights, weekends or travel time to and from the project. Refer to individual sections for additional training and instruction by manufacturer's trained specialists.
- B. Notify the Owner in writing at least three (3) weeks before the operating/instruction period begins. Do not commence until the Owner has issued written acceptance of the starting time and schedule.
- C. In addition to the operating/instruction period, organize and conduct a seminar to instruct the Owner's representatives in the operation and general preventative maintenance of equipment and systems provided at the completion of the project.
- D. Instruct Owner's operating personnel in proper starting sequences, operation, shutdown, and maintenance procedures, including normal and emergency procedures.
- E. Make arrangements to give instructions by system and not by building areas.
- F. Provide services of qualified personnel, including each sub-trade, each major equipment supplier to attend seminar and instruct on respective equipment or systems. Seminar shall be conducted by the Contractor and may be videotaped and attended by the Architect or Architect's representative.
- G. Submit seminar agenda, schedule and list of representatives to the Owner for review thirty (30) days prior to seminar. Confirm attendance at seminar by written notification to participants.
- H. At seminar, submit final copies of record drawings and operating and maintenance manuals to Owner.

- I. Submit a written record of the seminar, complete with an attendance list to the Owner.

3.17 OPERATING AND MAINTENANCE MANUALS

- A. Provide operating instructions and maintenance manuals for all equipment and materials furnished under this Division.
- B. Submit three (3) final copies of operating and maintenance data books for review at least ten (10) weeks before the completion date. Provide 8½-inch by 11-inch, expanding spine catalog binders bound with heavy red fabric, hot stamp lettering on front and spine identifying project name and owner's name. Assemble data in a completely indexed volume or volumes and identify the size, model, and features indicated for each item.
- C. Index the maintenance manual according to the following system:
 - 1. Tab – 1.0 Mechanical Systems: Title page identifying project, Owner, Contractor and Engineer with clear plastic protection cover.
 - 2. Tab – 1.1 List of HVAC, Plumbing and Fire Protection Drawings.
 - 3. Tab – 1.2 Description of Systems: Provide complete descriptions of the operating sequence for each system. Include detailed system description, with individual components described, and description of how components interface with others and to the complete system.
 - 4. Tab – 1.3 Operating Division: Provide information on locations of components, how to energize switches and controls, how components interface with other components, operation of controls including operational sequence, operational changes for cooling, heating or changeover, how to accomplish the changeover, complete troubleshooting sequence, and failure and safeguards to indicate if equipment goes off-line.
 - 5. Tab – 1.4 Maintenance and Lubrication Division: Provide general maintenance and lubrication schedule for major components and include daily, weekly, monthly, quarterly, semiannual and yearly checks and tasks. Explain how to execute maintenance tasks required for typical equipment such as bearings, drives, motors and filters. Compile this information for equipment separate from shop drawings.
 - 6. Tab – 1.5 List of Equipment Suppliers and Contractors: Provide list of equipment suppliers and contractors, including street addresses, web site addresses, fax and toll-free telephone numbers.
 - 7. Tab – Certification (2.0, 2.1, etc.): Include copy of test data on degreasing and flushing of hydronic systems, analysis of system water taken at time system was put into operation, hydrostatic or air tests performed on piping systems, equipment alignment certifications, copy of balancing data for air and water systems, copy of valve and damper identification and pipe color code and inspection approval certificates from authorities having jurisdiction.
 - 8. Tab – Shop Drawings and Maintenance Bulletins (3.0, 3.1, 3.2, etc.): Provide material received in compliance with clause "Submittals and Reviews".
- D. The manual divider and tabs shall be laminated mylar plastic and colored as follows:

| | | | | |
|-----------------------------|-----|---|------|--------|
| Mechanical Systems | 1.0 | – | 1.5 | Orange |
| Certification | 2.0 | – | 2.4 | Green |
| Shop Drawings & Maintenance | 3.0 | – | 3.17 | Yellow |
- E. Plastic tabs with typewritten card insertions will not be accepted.
- F. Maintenance information shall include complete lubrication, cleaning, and servicing data compiled in clearly and easily understandable format. Show model and serial number of each piece of equipment, complete lists of replacement parts, capacity ratings, and actual loads.
- G. Provide the following equipment maintenance information where applicable:

1. Identifying name and number
2. Locations (where several similar items are used, provide a list)
3. Complete nameplate data
4. Parts list
5. Performance curves and data
6. Wiring diagrams
7. Lubrication charts
8. Manufacturers' recommended operating and maintenance instructions with all non-applicable information deleted
9. List of spare parts recommended for normal service requirements
10. Assembly and disassembly instructions with exploded view Drawings where necessary
11. Trouble shooting diagnostic instructions where applicable

3.18 RECORD DRAWINGS

- A. The Contractor shall maintain on a daily basis at the Project site a complete set of Record Drawings. The Record Drawings shall initially consist of a set of blue-line prints or AutoCAD files of the Contractor's Coordination Drawings. The prints shall be marked or the AutoCAD files electronically updated to show the precise location of all buried or concealed work and equipment, including embedded piping and valves, and all changes and deviations in the Mechanical work from that shown on the Contract Documents. This requirement shall not be construed as authorization for the Contractor to make changes in the layout or work without definite written instructions from the Architect or Engineer. The updated Coordination Drawings shall be used to produce the final Record Drawings that shall be delivered to the Owner in AutoCAD electronic format media upon Project completion.
- B. Record dimensions clearly and accurately to delineate the work as installed. Suitably identify locations of all equipment by at least two (2) dimensions to permanent structures.

- C. The Contractor and Subcontractor shall mark all in-progress Record Drawings on the front lower right hand corner with a rubber stamp impression or an AutoCAD image similar to the following:

| |
|---|
| <p>RECORD DRAWING (3/8-inch high letters)</p> <p>To be used for recording Field Deviations and Dimensional Data Only (5/16-inch high letters)</p> |
|---|

- D. Upon completion of the work, the Contractor and subcontractors shall certify all Record Drawings on the front lower right hand corner adjacent to the above marking with a rubber stamp impression or an AutoCAD image similar to the following:

| |
|---|
| <p>RECORD DRAWING CERTIFIED CORRECT (3/8-inch high letters) (Printed Name of General Contractor)</p> <hr/> <p>(5/16-inch high letters) Date:</p> <hr/> <p>(Printed Name of Subcontractor)</p> <hr/> <p>(5/16-inch high letters) Date:</p> <hr/> |
|---|

- E. Prior to final acceptance of the Work of this Division, the Contractor shall submit properly certified Record Drawings to the Architect and Engineer for review and shall make changes, corrections, or additions as the Architect and/or Engineer may require to the Record Drawings. After the Architect's and Engineer's review, and any required Contractor revisions, the Record Drawings shall be delivered to the Owner on electronic media in AutoCAD format. The Architect and Engineer do not assume any responsibility for the accuracy or completeness of the Record Drawings.

3.19 CERTIFICATION

- A. Any certifications required by the Specifications, in addition to those required for shop drawings, product data, equipment and other items, are to be so certified in writing by the Owner, a Partner, or a Corporate Officer of the firm required to provide the Certification, or by another person duly authorized to sign binding agreements for and on behalf of the Owner, Partner or Corporation.

3.20 FINAL REVIEW

- A. At a time designated by the Owner, the entire system shall be reviewed for compliance with the Contract Drawings and Specifications. Be available at all times during this review.
- B. Demonstrate to the Owner and/or the Architect's personnel prior to the Final Review that systems and equipment have been properly balanced and adjusted and are in compliance with the requirements of the Contract Documents. After these demonstration tests are satisfactorily completed, but prior to the Final Review, submit a written certification that: 1) attests to the Contract Document compliance for this Project; and 2) certifies that the equipment and materials installed in this project contain no lead, asbestos or PCB. Prior to

the final review, the Contractor shall confirm the following items regarding the status of key elements of the work. Negative responses to any of the items indicate that the construction is not substantially complete, and the building is not ready for a final review. The Contractor shall confirm the following in writing:

1. Building air systems (fans, air handling units, etc.) are completely installed, commissioned and operating.
 2. Building hydronic systems are completely installed, commissioned, operating and pressure tested.
 3. Building management system is installed, commissioned and operating.
 4. Building has normal electrical power.
 5. The emergency or stand-by power system has been started-up, commissioned, and is standing by.
 6. Building systems have been cleaned.
 7. Seismic restraints have been inspected as specified. Any required special inspections have been completed.
 8. Building systems have been balanced and copy of balance report submitted to the Architect.
 9. Building fire and life safety systems have been tested and accepted by the local authorities. Any required special inspections have been completed.
 10. All final wiring connections have been rechecked.
 11. All base building lighting systems are completely installed and operating.
 12. The domestic cold water system has been installed, flushed, disinfected, tested and operating.
 13. The domestic hot water systems are completely installed, flushed, disinfected, tested and operating.
 14. The sanitary sewer and storm sewer systems are completely installed, operating, connected to the required city, public or private utilities and pressure tested.
 15. The fire protection systems are completely installed, operating, connected to the required city, public or private utilities and pressure tested.
 16. There are no deviations or non-compliance with the Contract Documents, or provide a detailed account of any and all deviations or non-compliance.
 17. All items on field review reports have been responded to in writing and are resolved to the satisfaction of the Owner.
 18. All outstanding items on submittals and shop drawings have been addressed in writing and are resolved to the satisfaction of the Owner.
 19. Schedule the final review only after providing written confirmation of all items above. Provide a minimum of ten (10) days notice.
- C. Operate the entire system properly with all systems balanced and all controls adjusted.
- D. Certificates and Documents required by the Contract shall be presented to the Architect at least two (2) weeks prior to the Final Review.
- E. After the Final Review, any changes or corrections noted as necessary for the work to comply with the Contract Documents shall be accomplished without delay in order to secure final acceptance of the work.

3.21 EARLY OCCUPANCY

- A. Be responsible for completing those systems, which are necessary to allow partial occupancy of the building even if systems in the unoccupied areas are incomplete.
- B. Verify and comply with requirements for temporary occupancy with the local Building Department.

END OF SECTION

SECTION 23 05 05

MECHANICAL SCOPE OF WORK

PART 1 – GENERAL

1.01 DESCRIPTION

- A. The General and Supplementary Conditions and Division 1 are a part of the requirements for the work under this Division of the Specification.

1.02 WORK INCLUDED

- A. The Contractors shall provide all labor, materials, tools, scaffolding, machinery, equipment, appliances and services necessary to complete the Heating, Ventilation, Air Conditioning, Plumbing and Fire Protection Work under this Contract. All systems and equipment shall be complete in every respect and all items of material, equipment and labor shall be furnished and installed for a fully operational system. The Contractor shall coordinate their Work with the Work of the other trades so as to resolve conflicts without impeding job progress or the Project construction schedule. Provide notice with the bid proposal of any general construction work required by this Division that is not indicated on the Structural, Architectural, or Mechanical/Electrical Drawings.

- B. The Contractors shall examine all the Architectural, Structural, and Electrical Drawings, and other Divisions and Sections of the Specifications in order to determine the extent of Work required to be completed under this Division. Failure to examine all the Contract Documents for this Project will not relieve the Contractor of the responsibility to perform all the Work required for a complete, fully operational and satisfactory installation.

- C. HVAC System Design System shall consist of the following:

1. Central Plant:

The central plant located in the Biological Science Facility will provide heating hot water and chilled water for use in both Sciences Facilities. It includes heat recovery chillers, chilled water pumps, condenser water pumps, plate and frame heat exchangers and well water heat exchanger that allows heat to be rejected to the earth during the cooling season, and removed from the earth during the heating season. The well water heat exchanger system will consist of ?include wells with submersible pumps and recharge wells to inject the well water back to the ground.

In the summer season the well water heat exchanger will be used for condensing purposes in the water cooled chillers. In the winter season, the chillers will be used to provide hot water from the condensers for heating. The heat source will be the heat generated in the Computational Lab building supplemented by the well water heat exchanger. Peak heating and cooling loads will be met with a roof mounted two closed circuit fluid cooler/coolers and two condensing boilers. The well water heat exchanger will be sized at approximately 2/3 of the peak load and designed to reach a minimum of 35 degrees F during the heating season and 95 degrees F during the cooling season.

- a. Administration (Office) Areas, Laboratory Offices, Support Areas and Common Use Areas in the CSF.

- (1) The HVAC system shall consist of rooftop custom air handling units. Included in each unit shall be supply and return fans with VFD's, outside air, return air and relief air dampers, mixing plenum, MERV 7 pre-filters, MERV 13 final filters, hydronic heating and cooling coils, indirect evaporative cooling and controls. The unit shall be

- capable of 100% economizer cycle.
- (2) Assume Aeon for equipment quality standard.
- (3) Zoning:
- (a) Separate zones shall be provided for conference rooms and manager type suites.
 - (b) Perimeter and interior areas shall be on separate zones.
 - (c) There shall be a maximum of 4 hard walled offices on a single zone.
 - (d) There shall be a maximum of 1200 sq. ft. of open "cubicle" type areas per zone.
 - (e) System will include electric heating coils for each perimeter zone in the CSF and hot water coils in BSF. Coils shall be integral with air terminal units. Fan powered air terminal units shall be used for all zones to maintain proper air movement.
- (4) The system shall utilize the ceiling plenum for return air.
- (5) Fan coil units shall be utilized to serve IT/Electric Closets/Stairs.
- b. Laboratories and Support Areas located in the Computational Science Facility
- (1) ~~Fan coil~~ Computer room type chilled water units ~~are~~ will be utilized to serve areas with high supplemental cooling loads in CSF.
- c. Laboratories and Support Areas located in the Biological Science Facility
- (1) The HVAC system shall consist of two (2) 100% outside air rooftop custom air handling units. Included in each unit shall be supply fans (using "Fan Wall" technology for redundancy) with VFD's, outside air damper, MERV 7 pre-filters, MERV 13 final filters, flat plate or heat pipe heat recovery section, indirect evaporative cooling section, hydronic heating coil, hydronic heating and cooling coils, and controls.
- (2) Each unit is sized for 50% of the total CFM requirement.
- (3) Assume Energy Lab for equipment quality standard.
- (4) Fan coil units ~~are~~ will be utilized to serve areas with high supplemental cooling loads.
- (5) Zone level hydronic heating coils shall be utilized to maintain space temperature setpoint at all times.
- (6) Pressure independent zone control valves shall modulate in unison with the fume hood, bio safety cabinet and general room lab exhaust control valves to maintain space pressure differential setpoints. Assume Phoenix Model Accell II Airflow control valves for equipment quality standard.
- d. Rooftop air-handling systems shall typically consist of
- (1) Face dampers at air inlet from intake plenum.
 - (2) 30 percent efficiency pre-filters.
 - (3) Chilled water cooling system.
 - (4) Hot water heating system.
 - (5) Access sections between coils and other components.
 - (6) Spring isolated airfoil supply fan or fans and return or exhaust fans.
 - (7) Diffusion plate to ensure proper mixing of air.
 - (8) 95 percent efficiency final filters.
 - (9) Stainless steel drains pans with "P" traps.
 - (10) Stainless steel inner lining of coiling coil sections, galvanized

aluminum liner in other sections.

(11) Additional design feature: Inverter duty premium efficiency motors.

2. Air Distribution Systems

The various areas in the building shall be served by central air-handling unit systems (AHUs) and supplemental fan coils units described elsewhere.

Air terminal units serve as a separation point between medium and low pressure ductwork, and include electric or hot water heating coils and sound attenuators as applicable and described in the previous section.

Ductwork shall be fabricated of G90 galvanized steel and insulated with 2-inch thick fiberglass insulation with vapor barrier.

Dampers for balancing airflow shall be provided at duct branches and splits.

3. Lab Exhaust Systems

The laboratories and fume hoods will be exhausted by three (3) MK Plastics fiberglass or epoxy coated metal exhaust fans. The fans are sized for 50% capacity each with one as standby manifolded together to a single exhaust air plenum.

The variable volume system will exhaust the labs via the fume hoods; other process exhaust and general exhaust registers using variable volume valves. The variable volume valves connected to the fume hoods will be coated for corrosion protection. General exhaust inlets with variable volume valves will be provided as required to supplement the fume hood exhaust system to maintain the minimum air change rate of 6 AC's/hr.

The exhaust fans will be provided with standby power to maintain the required airflow through the lab spaces and fume hoods during power outage. The lab supply air system will also be operational during any power outage.

Fume hood exhaust will be at minimum stack discharge velocity of 3000 FPM using a motorized make-up air damper. Exhaust air duct from the fume hood laboratory airflow control system dampers to the fans will be sized at a maximum velocity of 2200 FPM to minimize energy used to exhaust the air.

Refer to the detailed laboratory programming plans for quantities and locations of hoods and bio safety cabinets.

4. Lab Exhaust Duct and fan construction:

Galvanized Steel duct will be utilized for all general room exhaust and combined exhaust mains.

316 welded stainless steel exhaust ducts and plenums will be utilized for all fume hood connections until combined with general room exhaust at the main exhaust duct lines and for the ~~duct~~ducts located in the enclosed vertical shafts.

The centrifugal exhaust fans will be spark proof construction with motor out of the air stream, chemical resistant phenolic coating. Motorized isolation valve, and exhaust stack will be provided for each fan.

5. Laboratory Cold Rooms

The laboratory cold rooms will be served by water cooled direct expansion refrigerant systems. These systems will be supplied with condenser water from the central plant.

6. Building Management System (BMS)

Shall be a Distributed Digital Control (DDC) system complete with head-end, and ability to interconnect with existing PNNL systems via website. The BMS shall meet OPC-compliant communications capabilities. The BMS software will allow web-based connection for off-site management.

System will need to send alarm signals to security desk after normal working hours for initiation of protocol.

~~D. Fire Protection Systems Descriptions~~

~~1. Fire Service~~

~~a. System Description~~

- ~~(1) The building's fire protection system will be supplied from the site water main.~~
- ~~(2) The building standpipe and sprinkler system will be served by the site water system.~~

~~b. Design Criteria~~

- ~~(1) The fire service will be sized according to NFPA 24 and the minimum service size to the building will be 8 inches.~~
- ~~(2) Current water supply flow tests will be obtained from the city water department in order to determine the capacity of the water mains.~~
- ~~(3) The location of the fire department connection will be coordinated with the Architect. It is generally required that the location be at the first point of response by the fire department. There will be a fire hydrant within 100 feet of the fire department connection.~~

~~2. Standpipe System~~

~~a. System Description~~

- ~~(1) The building will be protected by a hydraulically designed, Class I standpipe system without hoses or hose cabinets.~~

~~b. Design Criteria~~

- ~~(1) The standpipe system will be designed and hydraulically calculated to provide a flow of 250 gpm at 100 psig residual pressure at the highest fire department valve located on the most remote standpipe. An additional flow of 250 gpm flow will be added at the next highest valve on that standpipe. Finally, a 250 gpm flow will be added at the next remote standpipe, bringing the total to 750 gpm.~~

~~3. Wet Pipe Sprinkler System~~

~~a. System Description~~

- ~~(1) The building will be protected throughout with hydraulically calculated sprinkler systems, which except for special protection needs, will be wet pipe systems. All areas of the building will be protected, including electrical rooms (switchgear, transformers, generators, closets, etc.), loading docks, stair towers, exterior canopies, and mechanical rooms.~~

b. Design Criteria

- (1) The sprinkler system for the building will be designed and installed in accordance with NFPA 13. All systems will be hydraulically calculated with a computer calculation program using the Hazen-Williams method. Areas designated, as Light Hazard Occupancy will be designed for a minimum sprinkler flow of 0.10 gpm per sq ft. Areas designated as Ordinary Hazard, Group 1 will be designed for a minimum sprinkler flow of 0.15 gpm per sq ft. The system demand will be based upon the most remote 1500 sq ft. The pipe sizing for the systems will be as required to satisfy the hydraulic demand, except the velocity in any portion of the system will not exceed 20 fps.

4. Gaseous Fire Protection System

a. System Description

- (1) Computer rooms and computer laboratories will be provided with portable fire extinguishers containing either FM-200 or Energen as the extinguishing agent.

E. Plumbing Systems Descriptions

1. Storm Water Drainage

a. System Description

- (1) A storm drainage system will be provided to convey rainwater from the roof of the building to site storm sewers 5 feet outside the building wall. Overflow drainage will be accomplished through overflow drainage system.

b. Design Criteria

- (1) The storm drainage system will be sized based on a maximum rainfall rate of 1 in/hr, which corresponds to a 100 year return, 60 minute rainfall. All design and installation will be in accordance with the Uniform Plumbing Code.

2. Sanitary Waste and Vent

a. System Description

- (1) A sanitary waste and vent system will be provided for all fixtures in the building. Plumbing fixtures will be drained by gravity through conventional soil, waste and vent stacks, building drains and building sewers to the site sewer 5 feet outside the building wall.
- (2) All fixtures will be trapped and vented to atmosphere. Vents will be extended through the roof.

b. Design Criteria

- (1) The sanitary waste system will be designed to maintain a minimum velocity of 2 fps. The sanitary vent system will be designed so that the differential pressure at any point in the building does not exceed 1" water column. All design and installation will be in accordance with the Uniform Plumbing Code.

~~3. Water Service~~

~~a. System Description~~

~~(1) Water will be supplied to the building from the municipal water system.~~

~~b. Design Criteria~~

~~(1) The water service will be designed to provide water to the building's fixtures and equipment at a minimum pressure of 35-psig. Maximum pressure will not exceed 80-psig and flow velocity will not exceed 8 fps. The building's service main size is anticipated to be 3-inch diameter. Estimated peak design flow demand for the building is 200-gpm.~~

~~4. Domestic Water~~

~~a. System Description~~

~~(1) Domestic water will be provided to all toilet room fixtures, electric water coolers, sinks, emergency shower/eyewash units, and any other devices and fixtures that require a domestic water supply. Hot water at 120°F will be provided to all fixtures and equipment requiring hot water using electric hot water heaters.~~

~~b. Design Criteria~~

~~(1) The piping will be sized to limit the velocity in any section of the system to a maximum of 8 fps for cold water system and 4 fps for hot water systems. Piping will be designed and installed in accordance with the Uniform Plumbing Code.~~

~~(2) Each water heater will be sized for 75% of the design hot water load.~~

~~5. Natural Gas~~

~~a. System Description~~

~~(1) Natural gas is anticipated to be piped to equipment (ex: boilers, water heaters) as required to meet building needs. Gas pressure will be determined based on equipment requirements. Natural gas will be extended to the building from the gas company's natural gas main in the street. It is anticipated that the gas meter(s) will be located at grade at the service entrance to the building.~~

~~(2) The estimated peak natural gas demand for the building is estimated to be 1,500,000-btuh.~~

~~b. Design Criteria~~

~~(1) All design and installation will be in accordance with the Uniform Plumbing Code.~~

~~(2) Natural gas will be supplied at a pressure of 2-psig. The piping will be sized to limit the pressure drop across the system to 10 percent or 0.2-psig.~~

~~(3) Natural gas shutoff valves, where required, will be located in accessible ceiling spaces.~~

~~(4) A seismic shut-off valve will provided at the building service.~~

~~6. Laboratory Waste and Vent~~

~~a. System Description~~

- ~~(1) Plumbing fixtures in laboratories and laboratory support spaces will be provided with a process drainage system separate from the sanitary drainage system. The process waste system will drain by gravity to a sampling basin located exterior to the building. The effluent from the sampling basin will discharge into the site sanitary sewer.~~

~~b. Design Criteria~~

- ~~(1) The process waste system will be designed to maintain a minimum velocity of 2 fps. The laboratory vent system will be designed so that the differential pressure at any point in the building does not exceed 1" water column. All design and installation will be in accordance with the Uniform Plumbing Code.~~

~~7. Laboratory Water System~~

~~a. System Description~~

- ~~(1) Laboratory water will be provided to all fixtures and equipment located in the laboratory and support areas. Hot water at 120°F will be provided to all fixtures and equipment requiring hot water.~~

~~b. Design Criteria~~

- ~~(1) The piping will be sized to limit the velocity in any section of the system to a maximum of 8 fps for cold water system and 4 fps for hot water systems. Piping will be designed and installed in accordance with the Uniform Plumbing Code.~~
~~(2) Each water heater will be sized for 75% of the design hot water load.~~

~~c. Equipment and Material~~

- ~~(1) The laboratory water system will be isolated from the domestic water system by reduced pressure backflow preventers.~~
~~(2) Laboratory hot water will be produced by duplex gas-fired storage-type water heaters.~~
~~(3) The hot water system temperature will be maintained by re-circulating the hot water through a continuous loop with an in-line circulating pump.~~
~~(4) Duplex alternating water softeners will be installed ahead of the water heaters.~~
~~(5) Water hammer arrestors will be provided at all solenoid valves and at other potential water hammer sources.~~

~~8. Non-Potable Water Systems~~

~~a. System Description~~

- ~~(1) Non-potable water system will provide make-up water to mechanical (HVAC) systems such as heating hot water, chilled water, and cooling towers.~~

b. ~~Design Criteria~~

- (1) ~~The piping will be sized to limit the velocity in any section of the system to a maximum of 8 fps. A reduced pressure backflow preventer will protect the domestic water supply and will be sized for 100% of the design load.~~

9. ~~High Purity Water~~

a. ~~System Description~~

- (1) ~~A system will be provided to produce and distribute water meeting the quality requirements of Clinical and Laboratory Standards Institute (CLSI).~~
- (2) ~~The specification for CLSI reagent Water is:~~
- (3) ~~Resistivity > 10.0 meg-ohm-cm at 25°C~~
- (4) ~~Total Organic Concentration: < 500 ppb~~
- (5) ~~Microbial < 10 CFU/ml~~
- (6) ~~This system will not be validated.~~
- (7) ~~Water of this quality will be produced from the facilities Lab soft water system.~~
- (8) ~~Pure water will be continuously circulated in closed loops to users throughout the laboratory and to the Clean Steam system if used.~~
- (9) ~~A pure water storage tank will be provided to ensure that water is available for distribution in the event that the production system is shut down.~~
- (10) ~~For use points that require a higher level of quality water, point of use polishing units will be provided.~~
- (11) ~~The system will be automatically monitored and controlled by a dedicated PLC based control system that will send a discrete alarm signal to the Building Management system in the event of deviations.~~

b. ~~Design Criteria~~

- (1) ~~The system design will be based on performing sanitation using peracetic acid solutions and will be performed by the pure water equipment supplier.~~
- (2) ~~The capacity of the production equipment and the storage tank will be based on the programmed use points and the following consumption estimates:~~
- (3) ~~Sinks: 10 gallons per day each~~
- (4) ~~Glass washers: 10 gallons per wash cycle~~
- (5) ~~2 wash cycles per day per washer~~
- (6) ~~20 gallons per day each~~
- (7) ~~Polisher: 2 gallons per day each~~
- (8) ~~The production equipment shall be sized to produce the total estimated consumption in 8 hours of operation. The capacity of the production system is estimated at 5 gpm.~~
- (9) ~~The storage tank will be sized to provide storage for 24 hours of estimated usage. The size of the storage tank is estimated to be 250 gallons.~~
- (10) ~~The distribution system will be designed to continuously circulate water at a velocity of 4-6 feet per second under no demand conditions, and a minimum velocity of 3 feet per second under maximum demand conditions. The maximum demand for the distribution system shall be based on the following demand rates and 40% diversity factor:~~
- (11) ~~Sinks: 1.0 gpm per outlet~~

- ~~(12) — Glass washers: 2-gpm per washer~~
- ~~(13) — Polishers: 0.25-gpm~~
- ~~(14) — The distribution system will be designed to maintain the temperature of the water under 80°F.~~
- ~~(15) — Reserve Capacity and Redundancy~~
- ~~(16) — The storage tank provides reserve capacity of 24 hours in the event of production system failure.~~
- ~~(17) — Distribution pumps will be provided.~~

~~10. — Nitrogen Laboratory System~~

~~a. — System Description~~

- ~~(1) — The nitrogen system will be provided to serve outlets as required by the Owner.~~

~~b. — Design Criteria~~

- ~~(1) — The nitrogen system will be designed to provide 30 psig nitrogen at the most remote lab outlet. The system will be sized based upon a load of 1 scfm per outlet and the total number of connected outlets connected to the system. Any point loads for specific equipment will be added to the outlet load after any diversity factors are applied.~~

~~11. — Laboratory Compressed Air~~

~~a. — System Description~~

- ~~(1) — Laboratory grade compressed air will be provided to all laboratory areas at a pressure of 100 psig and a dew point of -40°F. Compressed air will be provided as required by the Owner.~~

~~b. — Design Criteria~~

- ~~(1) — Compressed air piping system will be sized based on 1 scfm per outlet plus any flow required for individual pieces of equipment.~~
- ~~(2) — The piping system will be sized to limit pressure drop across the system to maximum of 10% of pressure regulator outlet pressure.~~
- ~~(3) — The compressors will be controlled by pressure switches in receiver set to operate between 100 and 115 psig. Each compressor will be sized for 75% of the maximum total demand. The compressors will be controlled on lead/lag/alternate basis.~~

~~12. — Laboratory Vacuum~~

~~a. — System Description~~

- ~~(1) — Laboratory vacuum air will be provided to all laboratory areas as programmed. Vacuum will terminate at laboratory outlets or equipment connections as required.~~

~~b. — Design Criteria~~

- ~~(1) — Laboratory vacuum piping system will be sized based on 0.5 scfm per outlet plus any flow required for individual pieces of equipment.~~
- ~~(2) — The piping system will be sized to limit pressure drop across the system to maximum of 3" of mercury vacuum.~~

~~(3) — The pumps will be controlled by pressure-switched in receiver set to operate between 25" and 29" of mercury vacuum. Each pump will be sized for 75% of the maximum total demand. The pumps will be controlled on lead/lag/alternate basis.~~

~~13. — Natural Gas~~

~~a. — Description~~

~~(1) — Natural gas is anticipated to be piped to equipment (ex: boilers, water heaters) as required to meet building needs. Gas pressure will be determined based on equipment requirements. Natural gas is anticipated to be a centrally piped and distributed system to serve lab and fume hood gas outlets. Natural gas will be extended to the building from the gas company's natural gas main in the street. It is anticipated that the gas meter(s) will be located at grade at the service entrance to the building.~~

~~(2) — The estimated peak natural gas demand for the building is estimated to be 5000 cubic feet per hour.~~

~~b. — Design Criteria~~

~~(1) — All design and installation will be in accordance with the Uniform Plumbing Code.~~

~~(2) — Natural gas will be supplied at a pressure of 2 psig and reduced to 7 inches W.C. for laboratory use. Piping will be sized to limit the pressure drop across the system to 10% of the supply pressure.~~

~~(3) — Natural gas shutoff valves, where required, will be located in [ceiling spaces] [a recessed wall valve box at 4'-6" above finished floor.~~

~~(4) — Natural gas piping system will be sized based on 5 cfh per outlet plus any flow required for individual pieces of equipment.~~

PART 2 – PRODUCTS

2.01 PARTIAL LIST OF WORK NOT INCLUDED IN MECHANICAL SPECIFICATIONS

- A. Electrical connections for motors and mounting of loose motors.
- B. Individual motor controllers except motor controllers furnished as integral parts of pieces of equipment.
- C. Pits for sewage ejectors and pumps; the Contractor shall be responsible for correct dimensions, layout, coordination, etc.
- D. All concrete work specified or indicated on the Structural, Architectural, and Mechanical/Electrical Drawings.
- E. Concrete equipment pads, concrete thrust blocks, and concrete fill for equipment and inertia bases. The Mechanical Subcontractor shall be responsible for providing the General Contractor with the correct dimensions, layout, etc., for all equipment.
- F. Metal architectural louvers (except as indicated on the Mechanical Drawings).
- G. Painting, except touch-up painting and as otherwise specified herein.
- H. Installing access doors in General Construction.

- I. Cooling tower supporting structure.
- J. Standby-power generator.
- K. Subsurface and landscape drainage.
- L. Utility mains and piping five (5) feet beyond the foundation walls unless shown otherwise on the Drawings.

END OF SECTION

SECTION 23 05 13

ELECTRIC MOTORS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
 - 1. Constant speed and two-speed squirrel cage, polyphase electric induction motors for mechanical equipment.
 - 2. Provide electric motors designed and rated for use on Alternating Current Variable Frequency Drives (VFD) where applicable.

1.02 SUBMITTALS

- A. Submit motors under the sections covering the driven equipment.
- B. Submit motor efficiencies at full load, 75 percent full load and 50 percent full load.
- C. Submit certified dimensions, insulation class, NEMA frame size, materials of construction, base details and mounting details.
- D. Include with the motor driven equipment submittal, the following motor information: manufacturer, horsepower, voltage, phase, hertz, rpm, full load efficiency. Include project specific wiring diagrams prepared by the contractor specifically for this work.
- E. Include manufacturer's instructions in the operating and maintenance manuals for the specific equipment. Include the following information if not previously documented on shop drawings: full load power factor, service factor, NEMA design designation, insulation class, and frame type.

1.03 STANDARDS

- A. ANSI/IEEE 112: Test Procedure for Polyphase Induction Motors and Generators
- B. ANSI/NEMA MG 1-1993 – Motors and Generators
- C. Underwriters Laboratories (UL)
- D. ANSI/NFPA 70: National Electric Code (NEC)
- E. Motors intended for variable speed applications shall have UL approval for use on “Generic” pulse width modulated and/or 6-Step waveforms. Motors requiring one specific manufacturer of VFD to meet the UL criteria are not acceptable.
- F. Motors shall conform to applicable requirements of NEMA, IEEE, ANSI, and NEC standards and shall be listed by UL for the service specified.
- G. Furnish motors for starting in accordance with utility requirements and compatible with starters as specified.

1.04 ELECTRICAL COORDINATION

- A. All starters, overload relay heater coils, disconnect switches and fuses, relays, wire, conduit, pushbuttons, pilot lights, and other devices required for the control of motors or electrical equipment are provided as specified by Division 26.

- B. Division 26 drawings and specifications show number and horsepower rating of all motors furnished by this Contractor. Should any discrepancy in size, horsepower rating, electrical characteristics or means of control be found for any motor or other electrical equipment after contracts are awarded, Contractor shall immediately notify the Architect of such discrepancy. Refer to Section 23 05 01 - Mechanical General Provisions.
- C. Furnish project specific wiring diagrams to Division 26 Contractor for all equipment and devices furnished under this section.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Constant Speed Applications: Toshiba Model E.Q.P., Magnetek E-Plus III, Baldor Super E, Reliance XE Premium, General Electric Energy Saver, Marathon Series E
- B. Variable Speed Applications: U.S. Electrical Motors “Inverter Grade”®, Baldor “Inverter Drive”® or approved equal

2.02 GENERAL

- A. Provide electric motors for driving the mechanical equipment. Motors shall be of proper power, construction and speed to suit the specified manufacturers of equipment. If other manufacturers of equipment are accepted, the proper adjustment of motor speed, torque and power must be included without additional cost. Submit drawings for review before the equipment is purchased.
- B. One-half horsepower and larger motors shall be rated 460 Volts alternating current (VAC) and suitable for operation on a 480 VAC (plus or minus 5 percent) – 3-phase – 60 hertz nominal electrical supply system.
- C. Fan coil unit and fan powered terminal unit motors shall be rated 277 VAC – single phase – 60 hertz and shall be provided with integral thermal overload protection.
- D. One-third horsepower and smaller motors shall be rated 120 VAC – single phase – 60 hertz and shall be provided with integral thermal overload protection.
- E. Motors shall be generally constant speed, squirrel-cage type, open drip-proof or totally enclosed fan cooled (TEFC) design. Single phase motors shall be high efficiency capacitor start, induction run, or split phase type as approved for the service.
- F. Motor temperature rise when operating on a variable frequency drive shall not exceed Class F insulation limits at full load, with 115 degrees C allowable winding hot spot temperature, across its nameplate speed and torque envelope. Sinewave temperature rise shall be Class F or better.
- G. Motors shall have minimum Class B insulation for continuous full load duty at 40 degrees C and a maximum altitude of 3300 feet above sea level. Where normal operating temperatures will exceed the Class B insulation rating, provide Class F insulation. For all motors driven by variable frequency drives, provide Class H insulation.
- H. Motors shall be of quiet operating type, guaranteed to fulfill the specified requirements without producing any objectionable sound exceeding room NC levels as specified. All belt connected motors shall have adjustable bases and set screws to maintain proper belt tension. Provide proper belt guards, in accordance with OSHA Standards.
- I. Motors and accessories shall be UL listed and comply with NEMA standards.

- J. Minimum Service Factor:
 - 1. Constant speed applications: 1.15.
 - 2. Variable speed application: Nameplate Sinewave Service factor shall be 1.15 or greater.

- K. Coordinate the NEMA type of each motor with the torque and inertia load of the equipment served, and the inrush current characteristics of the motor with the motor starter selection, so that all items furnished constitute a properly related package. Motor shall not operate in the 15 percent service factor range.

- L. Motors located in ducted air streams or subject to outside air elements shall be totally enclosed fan cooled; others shall be open drip-proof design. Motors 1 horsepower or larger shall have encapsulated stator windings of the epoxy or silicone type.

- M. Fan motors shall be capable of accelerating their respective fans from 0 revolutions per minute to design or synchronous revolutions per minute within a maximum of 10 seconds.

- N. All motors 1/2 horsepower and larger, except two-speed motors, specially wound motors and inline pump motors frame size 56 and smaller, shall be high efficiency design with full load efficiencies (in percent) which meet or exceed the values listed below when tested in accordance with NEMA MG:

| MOTOR EFFICIENCY BY MOTOR SIZE AND SPEED | | | | | | |
|--|----------|------|----------|------|----------|------|
| Horsepower | 1200 rpm | | 1800 rpm | | 3600 rpm | |
| | ODP | TEFC | ODP | TEFC | ODP | TEFC |
| ½ and ¾ | 80.0 | 80.4 | 82.1 | 82.7 | 79.1 | 78.5 |
| 1 | 82.5 | 82.5 | 85.5 | 85.5 | 80.0 | 85.5 |
| 1½ | 86.5 | 87.5 | 86.5 | 86.5 | 85.5 | 86.5 |
| 2 | 87.5 | 88.5 | 86.5 | 86.5 | 86.5 | 88.5 |
| 3 | 89.5 | 89.5 | 89.5 | 89.5 | 86.5 | 89.5 |
| 5 | 89.5 | 89.5 | 89.5 | 89.5 | 89.5 | 91.0 |
| 7½ | 91.7 | 91.7 | 91.0 | 91.7 | 89.5 | 91.7 |
| 15 | 92.4 | 91.7 | 93.0 | 91.7 | 91.0 | 91.7 |
| 20 | 92.4 | 92.4 | 93.0 | 92.4 | 92.4 | 92.4 |
| 25 | 93.0 | 92.4 | 93.6 | 93.0 | 93.0 | 93.0 |
| 30 | 93.6 | 93.0 | 94.1 | 93.6 | 93.0 | 93.0 |
| 40 | 94.1 | 93.6 | 94.1 | 93.6 | 93.6 | 93.6 |
| 50 | 94.1 | 94.1 | 94.5 | 94.1 | 93.6 | 94.1 |
| 60 | 95.0 | 94.1 | 95.0 | 94.5 | 94.1 | 94.1 |

- O. Explosion-proof motors or motors in hazardous locations shall be TEFC motors designed and listed to meet U.L. and NEC requirements for use in Division 1 and 2 hazardous locations as required by local regulatory agencies and insurance companies.
- P. Each motor shall be factory wired to a junction box mounted on the motor or on the driven piece of equipment to facilitate single point of field power connection under Division 26.

2.03 TWO-SPEED MOTORS

- A. Advise Division 26 Contractor and verify availability of speed combinations for all two-speed motors. Verify motor starter compatibility for two-speed, two winding and/or two-speed, one-winding.
- B. Unless otherwise indicated, three phase two speed motors shall be [single winding, consequent pole, variable torque type] [two winding, variable torque] and single phase motors shall be capacitor start capacitor run type having two capacitors in parallel with run capacitor remaining in circuit at operating speeds.

2.04 VARIABLE SPEED APPLICATIONS

- A. Motors used with variable frequency drives shall be designed specifically for use on AC inverter power and adjustable speed applications, with the following requirements:

1. Frame materials shall be cast iron, aluminum or rolled steel.
2. Motor insulation shall be Class H and designed to meet the voltage spike limits defined by NEMA MG1, Part 31, 1993. Insulation systems shall utilize 200-degree C magnet wire with a Pulse Endurance Index greater than 100. Insulation systems utilizing heavy film wire are not acceptable. Complete insulation of the slot, cell and phase groups is required. The system shall be rated for Class F rise or better.
3. Stator core designs shall be of high rigidity with reinforced end turn construction to minimize mechanical fatigue of the winding, and to reduce resonant noise. Varnished materials shall be double dip, double bake using polyester phenolic Class H varnish. Single dip and bake cycles are not acceptable.
4. Winding thermal protection, utilizing normally closed contacts, shall be sized to match the maximum safe operating temperature of the insulation system. Contacts shall open when winding temperature reaches 155 degrees C. Hazardous location motors shall have winding thermal protection sized as required to meet UL or as auxiliary devices where not required by UL.
5. Low loss electrical steel shall be utilized in the stator and rotor core assemblies.
6. Maximized copper content shall be utilized to achieve high motor efficiency and thermal transfer.
7. Rotor cores and/or assemblies shall be of a low vibration design that meets one-half of the NEMA MG1 recommended levels for balance.
8. The final motor design shall be evaluated by factory test on inverter power over the full range of speeds.

B. Variable Torque, Variable Speed Motors:

1. Motors shall meet NEMA design "B" performance levels. Design "A" motors are acceptable when higher than normal efficiencies are required.
2. Motors shall be nameplated for 6 to 60 hertz operation. Hazardous location motors may be nameplated 10 to 60 hertz.

C. Constant Torque, Variable Speed Motors:

1. Motors intended for constant torque applications shall be TEFC, TENV or TEBC (Totally Enclosed Fan Cooled, Totally Enclosed Non-Ventilated or Totally Enclosed Blower Cooled) construction.
2. TEFC motors rated for 3:1 constant torque on "GENERIC" inverter power shall meet NEMA design "B" levels. TENV motors and motors rated for speed ranges greater than 3:1 may be rated as NEMA design "A". TEBC motors shall meet NEMA design "B" levels.
3. Motors shall meet NEMA criteria for mechanical construction.

D. Nameplates:

1. Performance data for adjustable speed operation shall be stamped on a steel data plate and permanently attached to the motor frame.
2. The minimum amount of adjustable speed nameplate data shall include:
 - a. Application Type – Constant Torque, Variable Torque or Constant Horsepower.
 - b. Maximum approved continuous torque.
 - c. Approved RPM and frequency operating range.
 - d. Typical motor full load amps on VFD (inverter) power.

E. Motors used in variable speed applications shall have the following minimum NEMA nominal efficiency levels nameplated on the motor:

| | |
|-----------------|------|
| Open Drip-Proof | TEFC |
|-----------------|------|

| Horse-power | 2 Pole | 4 Pole | 6 Pole | 2 Pole | 4 Pole | 6 Pole |
|-------------|--------|--------|--------|--------|--------|--------|
| 1 | - | 85.5 | 80.0 | - | 85.5 | 81.5 |
| 1.5 | 82.5 | 85.5 | 84.0 | 84.0 | 85.5 | 85.5 |
| 2.0 | 84.0 | 85.5 | 86.5 | 86.5 | 85.5 | 87.5 |
| 3.0 | 84.0 | 89.5 | 88.5 | 87.5 | 89.5 | 90.2 |
| 5.0 | 87.5 | 89.5 | 88.5 | 88.5 | 90.2 | 90.2 |
| 7.5 | 87.5 | 91.0 | 91.0 | 91.0 | 91.0 | 91.0 |
| 10 | 88.5 | 91.0 | 91.0 | 91.0 | 91.7 | 91.0 |
| 15 | 89.5 | 92.4 | 91.7 | 91.0 | 92.4 | 91.7 |
| 20 | 91.0 | 93.0 | 91.7 | 91.0 | 93.0 | 91.7 |
| 25 | 91.7 | 94.1 | 93.0 | 91.7 | 93.0 | 92.4 |
| 30 | 93.0 | 94.1 | 93.6 | 91.7 | 93.6 | 93.0 |
| 40 | 93.0 | 94.1 | 94.5 | 92.4 | 93.6 | 94.5 |
| 50 | 93.0 | 94.5 | 94.5 | 93.0 | 94.5 | 94.5 |
| 60 | 93.6 | 95.0 | 94.5 | 93.0 | 94.5 | 94.5 |

- F. The above efficiency values represent motor designs rated for 230 VAC or 460 VAC at 1800 rpm nominal speed. Other base speeds and/or voltages may deviate from the above levels, but the NEMA Nominal efficiency must be provided at the time of the bid.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. When motor will be flexible coupled to the driven device, mount coupling to the shafts in accordance with the coupling manufacturer's recommendations. Using a dial indicator, check angular misalignment of the two shafts; adjust motor position as necessary so that the angular misalignment of the shafts does not exceed 0.002 inches per inch diameter of the coupling hub. Again using the dial indicator, check the shaft for run-out to assure concentricity of the shafts. Adjust as necessary so that run-out does not exceed 0.002 inches. Set all direct driven equipment with not more than one-half of the coupling manufacturer's recommended maximum tolerance for parallel and angular variance in alignment.
- B. Align all belt driven equipment to provide minimum wear on belts and drives, with belts properly tensioned.
- C. Mount motors on a rigid base designed to accept a motor, using shims if required under each mounting foot to get a secure installation.
- D. When motor will be connected to the driven device by means of a belt drive, mount sheaves on the appropriate shafts in accordance with the manufacturer's instructions. Use a straight edge to check alignment of the sheaves; reposition sheaves as necessary so that the straight edge contacts both sheave faces squarely. After sheaves are aligned, loosen the adjustable motor base so that the belt(s) can be added and tighten the base so that the belt tension is in accordance with the drive manufacturer's recommendations. Frequently recheck belt tension and adjust if necessary during the first day of operation and again after 80 hours of operation.

3.02 START UP

- A. Coordinate overload heater requirements with motor starter provider.
- B. Verify the proper rotation of each three-phase motor as it is being wired or before the motor is energized for any reason.
- C. Lubricate all motors requiring lubrication. Record lubrication material used and the

recommended frequency of lubrication. Include this information in the maintenance manuals

END OF SECTION

SECTION 23 05 14

VARIABLE FREQUENCY DRIVES

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following: Variable Frequency Drives (VFD) for mechanical equipment where indicated.

1.02 SUBMITTALS

- A. Product Data as specified, including outline dimensions, weights, power and control wiring schematics, and equipment schedule.
- B. IEEE – Standard 519 compliance calculation and harmonic analysis for this particular installation:
 - 1. Total harmonic voltage distortion and total harmonic current distortion. Provide calculations, specific to this installation, showing total harmonic voltage distortion is less than 5 percent.
 - 2. Input line filters shall be sized and provided as required by the manufacturer to ensure compliance with IEEE standard 519. All VFDs shall include a minimum of a 3 percent impedance reactor.
- C. Start-up Service Report and Guarantee.

1.03 QUALITY ASSURANCE

- A. Provide a 2-year unconditional parts and labor warranty on all VFD components. The warranty shall include all parts, labor, travel time and expenses.
- B. Referenced Standards:
 - 1. Institute of Electrical and Electronic Engineers (IEEE): Standard 519-1992, IEEE Guide for Harmonic Content and Control
 - 2. Underwriters laboratories: UL508C
 - 3. National Electrical Manufacturer's Association (NEMA): ICS 7.0, AC Adjustable Speed Drives
 - 4. IEC 16800 Parts 1 and 2
- C. Qualifications: VFDs and components shall be UL listed as a complete assembly. VFDs that require field-supplied external fuses for the VFD to be UL listed are not acceptable.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Variable Frequency Drives: Toshiba, ABB, Graham/Danfoss

2.02 AC VARIABLE FREQUENCY DRIVE

- A. Provide completely assembled VFD, factory-tested by the manufacturer. The VFD shall operate from a line overvoltage of 30 percent over nominal. The undervoltage trip level shall be 35 percent under the nominal voltage as a minimum.

- B. The alternating current variable speed drive system shall include the microprocessor based variable frequency controller, the required signal logic and control. The electrical drive equipment specified including the variable frequency controller and its associated microprocessor control system shall be of the same manufacturer. Coordinate with driven equipment supplier to ensure compatibility between drive and AC Motors.
- C. All equipment shall comply with the applicable requirements of the latest standards of ANSI, IEEE, and NEMA. The electrical equipment, as well as the design, construction, and installation thereof, shall comply with all the applicable provisions of the National Electrical Code and be ETL or UL approved.
- D. The variable frequency drive shall be mounted in a NEMA 1 enclosure for drives inside the building, NEMA 12 enclosure for drives in air handling plenum spaces, and NEMA 3R enclosure for drives outside the building. The control circuitry shall be isolated from the power circuitry.
- E. The manufacturer shall submit calculated line distortion percentages in accordance with IEEE STD-519, based upon the total connected horsepower and source kilovolt-amperes of the utility and emergency power distribution system. Request electrical data for calculation from the Division 26 contractor.
- F. The speed controller shall respond to a speed adjusting potentiometer from the VFD sequence panel when in the manual mode or shall respond to a milliamp or voltage electrical signal when operating in the automatic mode.
- G. The cabinet shall require front access only. The unit shall be suitable for operation in ambient air at 0 degrees C to 40 degrees C and up to 95 percent RH at rated load and switching frequency.
- H. The variable frequency controller shall convert 230 or 480 volt (plus or minus 30 percent) 3-phase, 60 hertz (plus or minus 3 percent) utility supplied or standby generator supplied power to variable frequency, variable voltage three-phase AC power for induction motor speed control. The controller shall be selected to have sufficient capacity to provide stepless speed control of the specified horsepower motors throughout a continuous speed range under a variable torque load not exceeding the motor full-load rating.

2.03 VARIABLE FREQUENCY CONTROLLER

- A. The controller shall be of the pulse width modulated (PWM) type and shall have three sections including a minimum 3 percent line impedance reactor as follows:
 - 1. AC-DC section (a 3-phase, full wave, half diode bridge or transistor bridge)
 - 2. Capacitor section
 - 3. 3-phase output module
- B. The controller shall be capable of performing the following functions:
 - 1. Adjustable linear timed acceleration and deceleration
 - 2. Plus or minus 0.5 hertz frequency stability
 - 3. 10:1 controlled speed range
 - 4. Manual/automatic operation
 - 5. Other functions as described
- C. Include the following protective devices and/or features:
 - 1. Regulator with self-contained test module or panel.
 - 2. Contactor shall be vacuum break design to carry specified current (OLT) on continual basis without damage (normal condition), designed to break specified locked rotor ampere current repeatedly without damage (abnormal operation). Entire VFD

- assembly shall be rated for minimum 100,000 amperes interrupting capacity root mean square symmetrical (AIC RMS).
3. AC overload protection to continuously monitor peak current and shut down the DC module gate signals if the instantaneous electrical trip motor current exceeds 180 percent of the controller full load current rating.
 4. Monitor lamps or LED read-out on VFD front panel to provide immediate indication of controller functions.
 5. Current limit.
 6. Adjustable volts/hertz.
 7. Adjustable offset voltage increases starting and accelerating torque capability.
 8. All output phase modules shall turn off instantly when a high DC bus occurs or when the current exceeds 150 percent of rated current.
- D. The following controller adjustments shall be contained on one regulator card of microprocessor control board:
1. Minimum hertz/maximum hertz
 2. Acceleration rate (Adjustable 0 to 125 seconds)
 3. Deceleration rate (Adjustable 0 to 125 seconds)
 4. Volts/hertz
 5. Offset voltage
- E. Provide a test panel or module to permit on-line monitoring and troubleshooting of the drive. Monitor the following regulator signals:
1. Internal power supplies
 2. Ramp generator output
 3. DC bus voltage

2.04 SAFETY CONTROLS & PROTECTIVE COMPONENTS

- A. The VFD shall be capable of starting into a rotating load (forward or reverse) and accelerate or decelerate to setpoint without safety tripping or component damage (flying start). The VFD shall also be capable of DC injection braking at start to stop a reverse spinning motor prior to ramp.
- B. The VFD shall be equipped with an automatic extended control power loss ride-through circuit, which shall utilize the inertia of the load to keep the drive powered. Typical control power loss ride-through for a fan load shall be 2 seconds minimum.
- C. The overload rating of the drive shall be 110 percent of its normal duty current rating for 1 minute every 10 minutes. The minimum full-load ampere rating shall meet or exceed the values in the NEC/UL table 430-150 for 4-pole motors.
- D. The VFD shall have an integral 3 percent impedance line reactors to reduce the harmonics to the power line and to add protection from AC line transients.
- E. The VFD shall be capable of sensing a loss of load (broken belt / broken coupling) and signal the loss of load condition. The drive shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus. Relay output shall include programmable time delays that allow for drive acceleration from zero speed without signaling a false underload condition.
- F. Provide surge reduction filter for electrical circuit lengths in excess of 200 feet.
- G. The following shall be provided:
 1. Motor thermal overload relays at the output for motor protection.
 2. Enclosure door interlocked disconnect switch.

3. All coils for relays and contactor shall be suppressed.
 4. Automatic Restart: Controller shall automatically attempt to restart five (5) times after a fault. After five (5) restarts, a manual start of the drive equipment is required.
 5. The following contacts shall be wired to terminal boards of users control and indication:
 - a. Motor running speed
 - b. Drive faults
 - c. Remote stop-starting
 6. A complete factory wired and tested bypass system consisting of an output contactor and bypass contactor. Overload protection and single phase protection shall be provided in both drive and bypass modes. Include door mounted manual by-pass switch with bypass contactor and, indicator light. Electronic bypasses are not acceptable.
- H. Drive faults shall consist of the following:
1. Motor thermal overload.
 2. AC input voltage dips to 60 percent or less of its nominal value.
 3. Drive output current exceeds 110 percent of controller full load rating.
 4. A fault condition in any of the 3 output power module phases.

2.05 ADJUSTMENTS AND CONTROLS

- A. All VFDs shall have the following operator adjustable components:
1. Two (2) programmable critical frequency lockout ranges to prevent the VFD from operating the load continuously at an unstable speed.
 2. PID Setpoint controller shall be standard in the drive, allowing a pressure or flow signal to be connected to the VFD, using the microprocessor in the VFD for the closed loop control. The VFD shall have 250 milliamp of 24 volts DC auxiliary power and be capable of loop powering a transmitter supplied by others. The PID setpoint shall be adjustable from the VFD keypad, analog inputs, or over the communications bus.
 3. Two (2) programmable analog inputs shall accept a current or voltage signal.
 4. One (1) programmable analog output.
 5. Two (2) programmable digital Form-C relay outputs. The relays shall include programmable on and off delay times. Default settings shall be for run and not faulted (fail safe).
 6. Seven (7) programmable preset speeds.
 7. Two independently adjustable acceleration and deceleration ramps.
- B. All VFDs shall have the same interface, including backlit LCD digital display and keypad, regardless of horsepower rating.
1. The keypad shall be used for local control, for setting all parameters, and for stepping through the displays and menus. The keypad shall be removable/lockable to the cabinet, capable of remote mounting, and shall have its own non-volatile memory. The keypad shall allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.
 2. The keypad shall include Hand-Off-Auto selections. When in "Hand", the VFD shall be started and the speed will be controlled from the up/down arrows. When in "Off", the VFD shall be stopped. When in "Auto", the VFD shall start via an external contact closure and the VFD speed shall be controlled via an external speed reference. Manual pilot devices are not acceptable.
 3. Display shall indicate drive frequency, output voltage or output current. Provide an indication of the activation of the drive protection features and/or status in plain English without the use of code abbreviations as follows:

- a. Overcurrent
- b. Overvoltage
- c. Current Limit
- d. Decel Voltage Limit
- e. Ground Fault
- f. Overtemperature
- g. I²T Protection
- h. Improper Input Voltage Selected
- i. Minimum/Maximum Speed Improperly Adjusted

C. Serial Communications:

1. The VFD shall have an RS-485 port as standard. The standard protocol shall be Modbus. Optional protocols that must be available are: Johnson Controls N2 bus, Profibus and DeviceNet.
2. Serial communication capabilities shall include, but not be limited to, run-stop control; speed set adjustment, proportional/integral/derivative PID control adjustments, current limit, and accel/decel time adjustments. A minimum of 15 field parameters shall be capable of being monitored. The DDC system shall be able to monitor if the motor is running in the VFD mode or bypass mode (if bypass is specified) over serial communications. The drive shall have the capability of allowing the DDC to monitor feedback as a minimum, with 5 additional:
 - a. Process variable feedback
 - b. Output speed/frequency
 - c. Current (in amps)
 - d. Percent torque
 - e. Power (kw)
 - f. Kilowatt hours (resettable)
 - g. Operating hours (resettable)
 - h. Relay outputs
 - i. Diagnostic warning and fault information
 - j. Remote VFD fault reset shall be possible
3. The VFD shall allow the DDC to control the drive's digital and analog outputs via the serial interface. The serial communications interface shall allow for DO (relay) control and AO (analog) control. This control shall be independent of any VFD function. The outputs can be used for modulating chilled water valves via the analog output, actuate a damper etc. In addition, all drive digital and analog inputs shall be capable of being monitored by the DDC system.

D. The following shall be furnished and mounted by the drive manufacturer and shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL 508 label:

1. Fused VFD only disconnect (service switch). Fast acting semi-conductor fuses exclusive to the VFD to allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection, maintaining bypass capability. Bypass designs, which do not have fuses, or that, incorporate fuses common to both the VFD and the bypass will not be accepted. Three contactor bypass schemes are not acceptable.
2. The following operators shall be provided:
 - a. Bypass Hand-Off-Auto
 - b. Drive mode selector
 - c. Bypass mode selector
 - d. Bypass fault reset
3. The following indicating lights (LED type) shall be provided. A test mode or push to test feature shall be provided.

- a. Power-on
 - b. External fault
 - c. Drive mode selected
 - d. Bypass mode selected
 - e. Drive running
 - f. Bypass running
 - g. Drive fault
 - h. Bypass fault
 - i. Bypass H-O-A mode
 - j. Automatic transfer to bypass selected
4. The following relay (form C) outputs from the bypass shall be provided:
- a. System started
 - b. System running
 - c. Bypass override enabled
 - d. Drive fault
 - e. Bypass fault- motor overload or underload due to broken belt
 - f. Bypass H-O-A position
5. The digital inputs for the system shall accept 24-volt or 115-volt AC (selectable). The bypass shall incorporate internally sourced 24-volt power supply and not require an external control power source.
6. Customer Interlock Terminal Strip – provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in Hand, Auto, or Bypass modes. The remote start/stop contact shall operate in VFD and bypass modes.
7. Dedicated digital input that will transfer motor from VFD mode to bypass mode upon dry contact closure for fireman’s override. Bypass mode shall force the motor to bypass operation and overrides both the VFD and bypass H-O-A switches and forces the motor to operate across the line.
8. The VFD shall include a “run permissive circuit” that will provide a normally open contact any time a run command is provided (local or remote start command in VFD or bypass mode). The VFD system (VFD or bypass) shall not operate the motor until it receives a dry contact closure from a damper or valve end-switch). When the VFD system safety interlock (fire detector, freezestat, high static pressure switch, etc) opens, the motor shall coast to a stop and the run permissive contact shall open, closing the damper or valve.
9. Class 20 electronic motor overload protection shall be included.
10. There shall be an internal switch to select manual or automatic bypass.
11. There shall be an adjustable current sensing circuit for the bypass to provide loss of load indication when in the bypass mode.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. The contractor shall install the drive and power wiring shall be completed in accordance with the recommendations of the manufacturer as outlined in the installation manual.
- B. Start-up Service: Provide certified factory-authorized start-up service for purposes of installation inspection, initial drive equipment setting, energization and adjustment. Start-up shall be provided for each drive by a factory authorized service center. A certified start-up form shall be filled out for each drive with a copy provided to the owner.
- C. Coordinate with equipment supplier to ensure compatibility between variable frequency drive and the motor supplied with the equipment.

- D. Division 26 shall mount and wire the drives in locations as shown on the Drawings.
- E. Maintain code required electrical clearance around all VFD cabinets.

END OF SECTION

SECTION 23 05 16

EXPANSION COMPENSATION

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Expansion loops and flexible expansion loops
 - 2. Pipe alignment guides and anchors

1.02 SUBMITTALS

- A. Product Data: For each type of expansion fitting indicated.
- B. Shop Drawings: Signed and sealed by a qualified professional engineer.
 - 1. Design Calculations: For thermal expansion of piping systems and selection and design of expansion fittings and loops.
 - 2. Anchor Details: Detail fabrication of each indicated. Show dimensions and methods of assembly.
 - 3. Alignment Guide Details: Detail field assembly and anchorage.
- C. Schedule: Indicate manufacturer's number, size, location, and features for each expansion fitting and loop.

1.03 QUALITY ASSURANCES

- A. Flexible expansion joints shall be AGA certified for use on gas piping.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Flexible Expansion Loops: MetraFlex, Hyspan
- B. Pipe Alignment Guides: Pipe Shields Series E2000 for insulated pipes; B-Line, Grinnell, Hyspan Series 9500 or MetraFlex for uninsulated pipes.

2.02 PERFORMANCE REQUIREMENTS

- A. Expansion compensator shall be capable of elongating & compressing to absorb 200 percent of maximum piping expansion between anchors.
- B. Pipe alignment guides shall be selected for both upward and downward motion.

2.03 FLEXIBLE EXPANSION LOOPS

- A. Provide flexible expansion loops of size and material noted on drawings.
- B. Flexible loops shall be designed to not impart thrust loads on the anchors. The loop shall consist of two flexible sections of hose and braid, two (2) 90-degree elbows, and a 180-degree return. Loops shall be installed in a neutral, pre-compressed, or pre-extended condition as required for application.

- C. Loops installed hanging down shall have a drain plug. Loops installed straight up may be fitted with an automatic air release valve that purges air from the high point of the loop. Loops installed in any position other than hanging down must have the 180-degree return supported.
- D. Joints for copper piping and fittings with solder-joint end connections:
 - 1. 2-inch and smaller: Bronze hoses and single-braid bronze sheaths with 340 psig at 450 degrees F minimum pressure ratings.
 - 2. 2½ to 4-inch: Stainless-steel hoses and single-braid, stainless-steel sheaths with 225 psig at 450 degrees F minimum pressure ratings.
- E. Joints for steel piping and carbon-steel fittings:
 - 1. End connections shall be threaded up to 2-inch and flanged for all other sizes.
 - 2. Joints, up to 2-inch: Stainless-steel hoses and single-braid, stainless-steel sheaths with 325 psig at 600 degrees F minimum pressure ratings.
 - 3. Joints, 2½ to 6-inch: Sstainless steel hoses and single-braid, stainless steel sheaths with 145 psig at 600 degrees F minimum pressure ratings.
 - 4. Joints up to 2-inch: Stainless steel hoses and single-braid, stainless steel sheaths with 90 psig at 600 degrees F minimum pressure ratings.
 - 5. Joints for 2½ to 6-inch: Stainless steel hoses and double-braid, stainless steel sheaths with 200 psig at 600 degrees F minimum pressure ratings.
 - 6. Joints for 8-inch and larger: Stainless steel hoses and double-braid, stainless steel sheaths with 120 psig at 600 degrees F minimum pressure ratings.

2.04 MISCELLANEOUS MATERIALS

- A. Guides shall be steel, factory fabricated, with bolted two-section outer cylinder and base for alignment of piping and two-section guiding spider for bolting to pipe.
- B. Bolts and Nuts: ASME B18.10 or ASTM A 183, steel, hex head.
- C. Washers: ASTM F 844, steel, plain, flat washers.
- D. Mechanical Fasteners: Insert-wedge-type stud with expansion plug anchor for use in hardened Portland cement concrete, and tension and shear capacities appropriate for application.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Provide at least two (2) guides each side of each expansion loop or compensator. Size guide cylinder to allow the full insulation thickness to be carried through the guide with ample clearance and without restricting the free movement of the pipe. Size guide cylinder for sufficient length to contain the total movement of the spider. Rigidly anchor pipe guide to building structure.
- B. Install expansion fittings according to manufacturer's written instructions in sizes matching pipe size in which they are installed. Align expansion fittings to avoid end-loading and torsional stress.
- C. Provide expansion loops or compensators as shown.
- D. Provide minimum of three (3) elbow offsets on branch pipe connections into mains and at each riser takeoff to allow piping flexibility and expansion.

- E. Install flexible loop within four (4) pipe diameters, both upstream and downstream, from a pipe guide or anchor.

END OF SECTION

SECTION 23 05 19

METERS, GAUGES AND THERMOMETERS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Flow meters
 - 2. Pressure gauges
 - 3. Thermometers
 - 4. Static pressure and filter gauges
 - 5. Pressure/temperature test ports

1.02 SUBMITTALS

- A. Submit list indicating use, operating range, total range and location.
- B. Submit manufacturer's data for instrument types, materials, accessories and installation.

1.03 QUALITY ASSURANCE

- A. Instruments shall be factory calibrated for the temperature and pressure of the systems in which they are installed.
- B. Pressure gauges shall be manufactured in accordance with ANSI Specification B-40-1 Grade 2A.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Thermometers and Pressure Gauges: Weiss, Terrice, Weksler, Taylor, Ashcroft
- B. Filter Gauges: Dwyer, Terrice, Orange Research
- C. Flow Meters: Onicon
- D. Pressure/Temperature Test Ports: Peterson Engineering, Terrice, Weksler

2.02 FLOW METERS

- A. Meter device shall be dual turbine element flow station set supplied by one manufacturer. Measuring station shall be stainless steel complete with safety shutoff valves and quick coupling connections and a permanent metal tag showing designed flow rates, meter readings for designed flow rates, metered fluid, line size and tag, station or location number.
- B. Stations shall be either nipple section or weld insert type and be rated to 275 pounds per square inch at 400 degrees F. Sensing elements shall be able to be rotated. Accuracy of the flow measuring elements shall be ± 2.0 percent and ± 2 percent repeatability as verified by independent laboratory reports. Output: 4-20 milliamps, supply voltage 24 volts DC.

2.03 PRESSURE GAUGES

- A. Process type in an impact resistant phenolic case, 4½-inch diameter glycerine filled phosphor

bronze bourdon tube rated to 600 pounds per square inch. Brushed stainless steel movement, ¼-inch brass socket and 1 percent mid-scale accuracy, black figures on white background. Provide brass needle valve and snubber. Weiss Instrument Model LF4UGY1 or equal. Where fluid temperature exceeds 212 degrees F provide non-liquid filled gauge Weiss Instrument Model NF4UGY1 or equal.

- B. For steam appliances provide dry type gauges with coil syphon.

2.04 PRESSURE/TEMPERATURE TEST PORTS

- A. Provide test ports ½ inch NPT made of brass with Nordel core. In addition, supply three (3) kits consisting of ¼ inch NPT pressure gauge, gauge adapter with 1/8-inch probe and protecting shield, bi-metal thermometer range 25 degrees F to 125 degrees F with 5-inch stem and 1¾-inch diameter dial, bi-metal thermometer range 20 degrees F to 240 degrees F with 5-inch stem and 1¾-inch diameter dial. Each kit to be provided in an impact resistant carrying case.

2.05 THERMOMETERS

- A. Adjustable angle dial face, bi-metal thermometer, 5-inch diameter with 2 degree F scale division, accurate to ±1 percent of scale range, Type 304 stainless steel case and bezel, shatterproof glass window, silicone filled. Weiss Model SF5VBM or equal.
- B. Thermometers shall be installed where shown on the Drawings or as specified. Pressure temperature ratings of each thermometer shall be suitable for the system in which it is installed. Thermometers shall have the following insertion lengths:
 - 1. Up to 5-inch pipe: 2½-inches
 - 2. 6-inch and 8-inch pipe: 4-inches
 - 3. 10-inch and larger pipe: [] inches
- C. Provide Type 304 stainless steel wells for all pipe mounted thermometers.
- D. Provide extended wells and stem length to accommodate insulation thickness for insulated pipe applications.

2.06 FILTER GAUGES

- A. Provide filters with direct reading gauges, 4-inch dial type, diaphragm actuated, in a metal case to monitor both primary and secondary filter banks. Dwyer Magnehelic Series 2000 or approved equal.
- B. Provide direct reading gauges, 4-inch dial type, diaphragm actuated, in a metal case with electrical control contacts to provide high pressure alarm at the BMS. Dwyer Photohelic Series 3000 or approved equal.
- C. Lettering shall be black figures on white background. Provide front recalibration adjustment.
- D. Provide gauges with the following differential ranges in inches water gauge:
 - 1. MERV 7 to 10 filters: 0.0 to 1.0
 - 2. MERV 11 to 12 filters: 0.0 to 2.0
 - 3. MERV 13 to 16 filters: 0.0 to 2.0
 - 4. MERV 17 and above filters: 0.0 to 4.0
 - 5. Activated carbon filters: 0.0 to 2.0
- E. Provide one gauge for each filter bank, suitable for flush or surface mounting. Include an air filter gauge accessory package consisting of mounting bracket, aluminum tubing, two static

pressure taps, and vent valves for each gauge.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Install flow meters according to manufacturer's installation instructions. Allow minimum ten (10) pipe diameters upstream of metering station and four (4) pipe diameters downstream or distances as recommended by the manufacturer.
- B. Provide one pressure gauge per pump. Install piping from pressure gauge to taps before strainers and on suction and discharge of pump. Refer to details on Drawings.
- C. For pipes smaller than 2½ inches, enlarge pipe for installation of thermometer wells.

3.02 SCHEDULE

- A. Flow Metering Stations: Chilled water, hot water and glycol systems where indicated on the Drawings.
- B. Pressure Gauges:
 - 1. Pumps
 - 2. Expansion tanks
 - 3. Glycol tanks
 - 4. Chillers inlet and outlet
 - 5. Heat exchangers inlet and outlet
 - 6. Boiler inlet and outlet
 - 7. All cooling coils
 - 8. All heating coils
 - 9. Storage tanks
 - 10. Other locations as indicated on Drawings
- C. Thermometers:
 - 1. All cooling coils inlet and outlet
 - 2. All heating coils inlet and outlet
 - 3. Heat exchangers inlet and outlet
 - 4. Chiller inlet and outlet
 - 5. Boiler inlet and outlet
 - 6. Other locations as indicated on Drawings
- D. Pressure/Temperature Test Ports:
 - 1. All automatic control valve's inlet and outlet
 - 2. Cooling and heating coils inlet and outlet
 - 3. Pumps concealed above ceilings
 - 4. Other locations as indicated on Drawings
- E. Filter Gauges:
 - 1. All air systems filter banks
 - 2. Constant volume system where bag filters specified
 - 3. Other locations as indicated on Drawings and in equipment specifications

END OF SECTION

SECTION 23 05 23

VALVES

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following valve types: Gate, Globe, Check, Ball, Butterfly, Grooved End, Low Pressure Steam, Automatic flow control valves.

1.02 SUBMITTALS

- A. Product Data: Manufacturer's latest published data for materials, capacity, performance intended service and installation.
- B. For each type of valve indicated, include body, seating, and trim materials; valve design; pressure and temperature classifications; end connections; arrangement; dimensions; and required clearances. Include list indicating valve and its application. Include rated capacities; shipping, installed, and operating weights; furnished specialties; and accessories.

1.03 QUALITY ASSURANCE

- A. Valves and valve construction shall be suitable for the pressure, temperature, and fluid quality of the service in which they are to be used.
- B. All valves shall be manufactured in accordance with ANSI, AWWA, ASTM, MSS-SP-70 & 80 (Manufacturers Standardization Society), standards and specifications.
- C. ASME B31.1 for power piping valves and ASME B31.9 for building services piping valves.
Exceptions: Domestic hot- and cold-water[, sanitary waste, and storm drainage] piping valves unless referenced.
- D. ASME B16.10 and ASME B16.34 for dimension and design criteria.
- E. NSF Compliance: NSF 61 for valve materials for potable-water service.
- F. Minimum test pressure for all valves shall be 1.5 times maximum system working pressure unless noted otherwise.
- G. Butterfly valves shall be suitable for dead end service and constructed of industrial design quality.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Gate Valves:
 - 1. Bronze: Grinnell, Crane, Cincinnati, Nibco
 - 2. Cast Iron: Crane /Jenkins, Crane/Stockham, Walworth, Grinnell, Milwaukee
- B. Check valves:
 - 1. Bronze: Crane, Hammond, Milwaukee, Nibco, Powel, Stockham

2. Gray-iron swing check: Crane, Hammond, Milwaukee, Nibco, Powell, Stockham, Victaulic
 3. Spring-loaded, lift-disc check valves: Metraflex 900 series or equal by Milwaukee, Mueller Steam, Nibco, Val-Matic, Victaulic
- C. Globe Valves: Cincinnati, Crane /Jenkins, Crane/Stockham, Hammond Walworth, Grinnell, Milwaukee, Nibco
- D. Ball Valves: Apollo 70-100/200 series, or equal by Hammond, Milwaukee, Nibco, Stockham
- E. Butterfly Valves:
1. Single- or no-flange: Grinnell 8000 or equal by Demco NE, Crane QuarterMaster, Stockham, DeZurik, Nibco, Keystone
 2. Flanged: Keystone Fig 222 or equal by Grinnell, Mueller, Tyco
 3. Grooved-End, Ductile-Iron: Victaulic 300 and 709 series or equal by Grinnell, Nibco
 4. High-pressure: Crane Flowseal, Jamesbury, Tyco, DeZurik
- F. Grooved End Valves: Victaulic, Grinnell, Gustin Bacon
- G. Automatic Flow Control Valves: Griswold, Flow Design
- H. Balancing Valves: Armstrong Type CBV, B&G Circuit Setter Plus, Taco Accu-Flo, Tour & Andersson STAS/STAD, Victaulic series 786/787
- I. Low pressure steam/condensate valves (15 psig or less):
1. Gate: Crane, Hammond, Milwaukee, Nibco, Powell, Stockham
 2. Butterfly, 4-inch and larger: DeZurik HP, Jamesbury 815, Flowseal HPBV, Keystone K-Lok
 3. Globe: Crane, Hammond, Milwaukee, Nibco, Powell, Stockham
 4. Swing check: Crane, Hammond, Milwaukee, Nibco, Powell, Stockham
 5. Spring-loaded check, up to 2-inch: ConBraCo 61 series, Mueller, Nibco
 6. Spring-loaded check, 2½-inch and larger: Metraflex 900 series or equal by Milwaukee, Mueller Steam, Nibco

2.02 GENERAL

- A. Provide valves of same manufacturer for the same service. Valve pressure and temperature ratings shall be not less than indicated and as required for system pressures and temperatures.
- B. Provide valves with manufacturer's name and pressure rating clearly and permanently marked on the outside of body.
- C. Provide valves suitable for connection to adjoining piping as specified for pipe joints.
- D. Valves shall be full pipe size unless noted otherwise.
- E. Provide valves identified for future connection with lockable handles.
- F. Valve seats shall be rated to 240 degrees F minimum without deterioration.

2.03 GATE VALVES

- A. Provide gate valves for isolation in steam and water systems, and as shown on Drawings or specified for other systems.

- B. Two inch and smaller valves shall be rising stem, screwed bonnet, inside screw and wedge gate, bronze body and trim with screwed ends.
- C. Two and one-half inch and larger valves shall be rising stem, bolted bonnet, outside screw and yoke, wedge gate, iron or steel body, bronze trim with flanged ends.
- D. Gate valves shall be backseating and suitable for repacking under pressure. Packing shall be asbestos free.
- E. Steam Service:
 - 1. Up to 150 psig, 2-inch and smaller: Class 200, bronze body, bronze trim, threaded ends, solid wedge, stainless steel seat rings, rising stem, non-asbestos packing, union bonnet, malleable iron hand wheel.
 - 2. Up to 150 psig, 2-1/2-inch and larger: Class 150, ASTM 216, Grade WCB, steel body, O.S. & Y., stainless steel or 12% chrome faced wedge, Stellite seat, flanged, bolted bonnet, non-asbestos packing.
 - 3. Over 150 psig, 2-inch and smaller: Class 800, API 602, A105 forged steel body, stainless steel wedge and trim, malleable iron hand wheel, bolted bonnet, bolted gland.
 - 4. Over 150 psig, 2-1/2-inch and larger: Class 300, ASTM 216, Grade WCB, steel body, O.S. & Y., stainless steel wedge, steel seat, flanged ends, bolted bonnet.

2.04 GLOBE VALVES

- A. Provide globe valves for throttling in steam and water systems.
- B. Two inch and smaller valves shall be inside rising stem, screwed bonnet with screwed ends.
- C. Two and on-half inch and larger valves shall be rising stem, outside screw and yoke, bolted bonnet and flanged ends.
- D. Globe valves shall be suitable for repacking under pressure. Packing shall be asbestos free.
- E. Valve seats shall be nickel alloy or stainless steel.
- F. Steam Service:
 - 1. Up to 150 psig, 2-inch and smaller: Class 200, bronze body, stainless steel plug disc and seat rings, malleable iron hand wheel.
 - 2. Up to 150 psig, 2-1/2-inch and larger: Class 150, ASTM 216, Grade WCB, steel body, O.S. & Y., stainless steel or 12% chrome faced disc, Stellite seat rings.

2.05 CHECK VALVES

- A. Swing Type: Provide for water and low pressure steam services: 2 inch and smaller with screwed bonnet, screwed end; 2½ inch and larger with bolted bonnet, flanged end. Valves shall have renewable bronze seat and disc.
- B. Silent Type: Provide on pumps larger than 2 inch discharge. Valves shall have cast iron body with bronze or stainless steel trim, spring loaded, and to be of the center guide type, with flanged end.
- C. Steam Service:
 - 1. Up to 150 psig, 2-inch and smaller: Class 200, bronze body, threaded ends, renewable nickel-alloy or bronze seats and discs, 45 degree seating angle, threaded cap.

2. Up to 150 psig, 2-1/2-inch and larger: Class 150, ASTM 216, Grade WCB, steel body, renewable stainless steel seats and discs, 45 degree seating angle, bolted cap, non-asbestos gasket.

2.06 BALL VALVES

- A. Provide ball valves for isolation and as drain valves, in water systems up to 200 degrees F and pipe sizes up to 2 inch.
- B. Provide ball valves of the bronze top-entry body type, having a straight-through full port flow passage. Design to permit disassembly without removing body from line. Provide extended neck where used on insulated piping.
- C. Provide stainless steel or chrome plated brass/bronze ball; conventional port.
- D. Construct seats and gland packing of glass filled teflon with a threaded packing gland follower; blowout-proof stem rated at 600 psig WOG.
- E. Provide stem extensions when valves are installed in insulated pipe with vapor barrier so valve handles clear insulation. Lever handle shall be vinyl covered.
- F. Provide lever for quarter turn operation; lever to indicate open or closed position.
- G. When used as drain valves, provide with hose thread and brass cap with chain. Cap shall be rated for full system pressure.

2.07 BUTTERFLY VALVES

- A. Provide butterfly valves for isolation in water systems up to 200 degrees F and pipe sizes 2½ inch and larger. Provide butterfly valves for isolation in steam systems for pipe sizes 4-inch and larger.
- B. Butterfly valves shall have ductile or cast iron lug body, Type 416 stainless steel stem with bronze bushings which isolate stem from body and aluminum bronze disc.
- C. The stem journals shall be a multiple seal design providing for completely independent seals. The stem to disc connection shall be a machined drive mated to a machined socket in the disc. Positive stem retention shall be provided to permit removal of handle or actuator while under full operating pressure. Provide extended neck where used on insulated piping.
- D. The valve seats shall be replaceable resilient elastomer bonded to a phenolic back.
- E. Valves up to size 6 inch shall be supplied with multi-position handles; size 8 inch and over shall be supplied with enclosed worm gear operator.
- F. Valve body shall be full-lug pattern to comply with MSS-SP-67 and be compatible with ANSI pattern flanges of appropriate pressure rating.
- G. Valve shall provide tight shutoff up to valve rating on dead-end or isolation service without the use of downstream flanges.
- H. Steam Service: ANSI Class 150, ASTM 216, Grade WCB suitable for continuous duty in saturated steam, cast steel body, stainless steel shaft, stainless steel or nickel plated steel disc, reinforced high temperature [polymeric] [teflon] resilient seat with full supporting stainless steel ring. Wafer type. Manual worm gear operator with high ratio (18 to 1 minimum). Provide stem extensions where required for operator and handle to clear vapor barrier insulation.

2.08 GROOVED END VALVES

- A. Valve model and series numbers listed are based on Victaulic.
- B. Butterfly Valves:
 - 1. Series 700 sizes 2 inch through 6 inch: All valves shall be of triple seal designed for bubble-tight, shutoff service up to 200 pounds per square inch and vacuum service to 29.9 inches of mercury gauge. Disc seal (EPDM) rated for service up to 230 degrees F.
 - 2. Series 300 sizes 2 inch through 12 inch: Grooved end butterfly valve for all services up to 300 pounds per square inch. Valve body of ductile iron with grooved end designed to accept grooved mechanical couplings. Valves shall be bi-directional and provide bubble-tight shutoff and dead-end service at full rated working pressure. Disc seal (EPDM) rated for service up to 230 degrees F.
 - 3. Series 709 sizes 14 inch through 24 inch: Single piece ductile iron cast body, PPS coated on the inside for corrosion resistance. The ductile iron disc rides on stainless steel stems with stainless steel wetted hardware. The EPDM seal, mounted on the offset disc, seals on the PPS seal for bi-directional working pressure of 175 pounds per square inch, 230 degrees F.
 - 4. Provide extended neck where valve is used on insulated piping.
- C. Ball Valves:
 - 1. Series 721 ball valves size 2 inches and under: Designed for 600 pounds per square inch bubble-tight working pressure.
 - 2. Provide extended neck where valve is used on insulated piping.
- D. Check Valves:
 - 1. Series 715, 716 and 711 sizes 2½ inch through 12 inch Dual Disc Check Valves: check valves with spring activated, dual disc, non-slamming design. Valves shall be suitable for horizontal or vertical installation and rated for working pressures up to 300 pounds per square inch, 230 degrees F.
 - 2. Series 712 Swing Check Valves sizes 2 inch through 4 inch: Full port opening and bolted coupling closure access. Valves shall be rated for 300 pounds per square inch working pressure, 230 degrees F, "E" EPDM Disc Seat ASTM D-2000.

2.09 AUTOMATIC FLOW CONTROL VALVES

- A. Provide automatic pressure-compensating flow control valves with extended valve body and dual temperature/pressure test ports. Wafer type body is not acceptable.
- B. Automatic flow valve shall be manufactured in one piece and to consist of ground joint union, flow control and pressure/temperature test ports.
- C. Valves shall be factory set to control the flow rate within 5 percent of the selected rating over an operating pressure differential of at least 10 times the minimum required for full flow conditions.
- D. The control mechanism of the valve shall consist of a self-contained, open-chamber cartridge assembly with unobstructed flow passages that eliminate accumulation of particles and debris. All internal working parts shall be Type 300 stainless steel. No plated materials are acceptable.
- E. The stainless steel cartridge assembly shall consist of a spring-loaded cup. The cup shall be guided at two points and shall utilize the full available differential pressure across the valve to actuate the cup and thereby reduce friction and hysteresis and eliminate binding. It shall have a thin orifice plate for self cleaning of the variable inlet ports over the full control range.

Cartridge must be removable in one piece.

- F. Cast iron valve bodies shall be provided with inlet and outlet ports suitable for connection of instruments for verification of flow rates, and shall be marked to show direction of flow. Valve bodies shall be rated for use at not less than 150 percent of system designed operating pressures.
- G. Provide a metal identification tag, with chain, for each installed valve. The tag shall be marked with zone identification, valve model number and rated flow in gallons per minute.
- H. Correct flow shall be verified by establishing that the operating pressure differential across the valve taps is within the range indicated on the submittal data sheet for that model number.
- I. The pressure measuring apparatus shall be portable and consist of a pressure gauge with a 4½ inch diameter dial, instructions, hoses, connections and a carrying case. Automatic flow control valves shall be furnished with fittings suitable for use with the measuring instruments specified.

2.10 BALANCING VALVES

- A. Balancing valve for water service shall be of the calibrated balance valve type with capped pressure/temperature ports, positive shutoff angle globe type, with adjustable memory stop and indicator.
- B. Valves 2" and smaller: Bronze or copper alloy body with calibrated ball, globe or venturi/valve arrangement, integral pointer and calibrated scale to register degree of valve opening. Provide memory stop, drain tapping, threaded or soldered ends, with or without integral unions, P/T or Shraeder type pressure taps with integral check valves and seals and adjustable memory stop. Valves shall be suitable for 200 psig water working pressure at 250 degrees F.
- C. Provide a pressure differential meter, hoses and carrying case. The kit shall include a six-inch diameter gauge with 270 degree arc readout. Gauge, with accuracy of plus or minus 1percent of full scale, shall be suitable for the differential pressures of the valves supplied for this project, with over-range protection. Include color-coded hoses ten feet minimum in length with brass connectors suitable for connection to the low and high pressure connections on the balance valves. Provide instrument valving so meter can be vented and drained. Pressure and temperature rating shall be equal to that of the valves. Provide meter and all accessories in a durable case with carrying handle. The meter is applied directly across the pressure/temperature ports on the calibrated flow control valves. Provide a calibrated conversion calculator to convert pressure drop to flow in gallons per minute. Barton 247A, Midwest 809 or equal.

2.11 DRAIN VALVES

- A. Drain Valves: ¾-inch ball valve, short ¾-inch nipple or adapter, with ASME B1.20.7, hose-thread outlet and cap.
 - 1. Metal Piping: Metal or plastic valve, nipple, or adapter, and cap of material compatible with piping and system liquid.
 - 2. Plastic Piping: Plastic valve, nipple, or adapter, and cap of same material as or compatible with piping, and compatible with system liquid.

2.12 VALVE ACTUATORS

- A. Provide chainwheel for attachment to valves, of size and mounting height, as specified. Construct of cast or ductile iron, with adjustable sprocket rims and chain guides. Use galvanized or brass chain and chain closure links to form a continuous loop of chain at each operator.

- B. Provide gear drive for quarter-turn valves 8-inch and larger.
- C. Provide handwheel for valves other than quarter-turn types.
- D. Provide lever handle for quarter-turn valves-6-inch and smaller, except plug valves.
- E. For plug valves with square heads, furnish Owner with one wrench for every 10 plug valves, for each size square plug head.

PART 3 – EXECUTION

3.01 PRE-INSTALLATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling. Protect internal parts against rust and corrosion. Protect threads, flange faces, grooves, and weld ends.
- B. Set angle, gate, and globe valves closed to prevent rattling. Set ball and plug valves open to minimize exposure of functional surfaces. Set butterfly valves closed or slightly open. Block check valves in either closed or open position. Maintain valve end protection.
- C. Store valves indoors and maintain at higher than ambient dew-point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
- D. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.
- E. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations. Examine threads on valve and mating pipe for form and cleanliness. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage. Do not attempt to repair defective valves; replace with new valves.
- F. Properly align piping before installation of valves in an upright position.

3.02 INSTALLATION

- A. Install valves so that they are accessible for repacking. Locate valves for easy access and provide separate support where necessary.
- B. Install valves with stem vertical and handle up wherever possible, never with stem below horizontal position.
- C. Install valves with operating clearance for handle and stem in position to allow full stem movement.
- D. Install swing check valves in horizontal position with hinge pin level. Install dual-plate check valves in horizontal or vertical position, between flanges. Install lift check valves with stem upright and plumb. Provide swing check valves where specified, detailed, and at steam condensate lines where they rise at outlet of traps. In such cases, provide isolation valves to allow repair or replacement of check valve.
- E. Install isolation valves on equipment so that valve and piping do not interfere with equipment removal or maintenance. Install unions or flanges on equipment side of valves arranged to allow service, maintenance, and equipment removal without system shutdown.

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

3.03 VALVE ACCESSORIES

- A. Provide valves of a design permitting packing while open and under pressure.
- B. Provide 1 inch drain valves with threaded ends for hose connections at drain points, at main shutoff valves, low points of piping systems, bases of vertical risers, and at equipment.
- C. Steam/condensate bypass:
 - 1. Install pressure equalization/warm up bypass line with a globe valve around main steam shut-off valves (gate and butterfly) 4-inch and larger. Provide bypass gate valve as specified above to meet requirements of operating pressure and temperature of high pressure steam line. Provide bypasses sizes according to the following:
 - a. Up to 8-inch valve: ¾-inch bypass
 - b. 10 to 12-inch valve: 1-inch bypass
 - c. 14 to 16-inch valve: 1¼-inch bypass
 - 2. Bypass lines shall be made with weldolet taps at the top centerline of the steam main line on each side of the shut-off valve and with the line completely above the elevation of the top of the main steam shut-off valve. Bypass line piping shall be ASTM Type F extra strong (schedule 80) black steel pipe with ASTM A126/ANSI B16.4 Class 250 extra heavy cast iron threaded fittings. Union in bypass line to be 2000 pound W.O.G. forged steel ground joint union.
- D. Provide required manual or automatic vent valves at high points of piping systems to facilitate venting of air and to ensure quiet operation. Provide piping from air vents to a drain.
- E. Provide renewable bronze seat rings and bronze spindles for cast iron body valves.
- F. Provide chain operated sheaves and chains for all valves, 2½ inch and larger, which are more than 8 feet above the floor in mechanical equipment rooms. Extend chains to within 60 inches above finished floor.
- G. Provide an isolation valve in the common supply line and an individual balance valve in the return line from each hydronic coil, heat exchanger, and all heat transfer elements.
- H. Provide an isolation valve in each supply riser near main and a balancing valve in each return riser near main.
- I. Provide pressure/temperature test port fittings at each side of globe valves.
- J. Use plastic and plastic-lined valves with wetted surfaces made of same material as or compatible with piping and compatible with system liquid.

END OF SECTION

SUPPORTS, HANGERS, ANCHORS AND SLEEVES

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this section shall include, but is not limited to, the following:

1. Pipe, duct and un-isolated equipment hangers, anchors and supports
2. Sleeves, escutcheons
- ~~3. Through-penetration firestopping in fire-rated construction and through-penetration smoke-stopping in smoke partitions, including methods and materials applied in penetrations and unprotected openings to limit spread of heat, fire, gasses and smoke.~~
3. Reference Division 7 for fire stopping requirements.

1.02 REFERENCES

A. Manufacturer's Standardization Society of the Valve and Fittings Industry Inc.:

1. MSS SP-58 Pipe Hangers and Supports - Materials, Design and Manufacturer
2. MSS SP-69 Pipe Hangers and Supports - Selection and Application

~~B. Underwriters Laboratories:~~

~~1. UL Fire Resistance Directory~~

- ~~a. Through-penetration firestop devices (UL-XHCR)~~
- ~~b. Fire resistance ratings (UL-BXUV)~~
- ~~c. Through-penetration firestop systems (UL-XHEZ)~~
- ~~d. Fill, void, or cavity material (UL-XHHW)~~

~~2. UL 1479 Test Method for Fire Tests of Through-Penetration Firestops, including optional air leak test~~

- ~~3. UL Component Listing Test Criteria~~
- ~~4. Warnock Hersey~~

~~C. American Society for Testing and Materials Standards: ASTM E 814 – 88: Standard Test Method for Fire Tests of Through-Penetration Firestops.~~

B. CIE/DIN Age Testing.

1.03 SUBMITTALS

A. Include on ductwork and piping shop drawings a layout of masonry and concrete floor and wall sleeve locations for pipes and ducts. Include elevations and sleeve sizes.

~~B. Submit product data on through-penetration firestop. Submittal data for firestopping systems shall include the UL System Numbers listed in the UL Building Materials Directory under which the material was tested in accordance with ASTM E 814 (UL 1479) for use in a Through-Penetration Firestop System. Where there is a firestop application that has not been tested by UL, obtain from the manufacturer an engineered judgment that the proposed application of the firestop product is suitable. Submit the engineered judgment to the authority having jurisdiction.~~

1. Product Data: Manufacturer's specifications and technical data including detailed specification of construction and fabrication, manufacturer's installation instructions

and details of each proposed assembly identifying intended products and applicable UL system number or UL classified devices.

2. Shop Drawings: Indicate dimensions, description of materials and finishes, general construction, specific modifications, component connections, anchorage methods, hardware, and installation procedures, plus the following specific requirements:
 - a. Manufacturer or manufacturer's representative shall provide qualified engineering judgments and drawings relating to non-standard applications as needed.

- B. Submit details of hangers, anchors and supports for each pipe size and service, ductwork and individual pieces of equipment.

1.04 QUALITY ASSURANCE

- A. Hangers and supports to be constructed and applied according to the following standards:
 1. Power Piping Code: ANSI B31.
 2. Duct Hangers: Provide hangers as required per SMACNA Standards for ductwork pressure classification.
~~3.NFPA standards for fire protection system piping.~~
~~4.Firestopping materials shall have been tested to provide fire rating at least equal to that of the construction.~~
 3. Deliver products in original, unopened packaging with legible manufacturer's identification.
 4. Mechanical sleeve seals shall be manufactured in an ISO 9001:2000 certified facility.
 5. Submit written guarantee agreeing to repair or replace joint sealers which fail in joint adhesion, extrusion resistance, migration resistance, or general durability or appear to deteriorate in any other manner not clearly specified by submitted manufacturer's data as an inherent quality of the material for the exposure indicated. The guarantee period shall be one year from date of substantial completion.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Pipe Hangers: Anvil, Fee & Mason, Elcen, Tube-Turn, F&S, Pipe Shields, B-Line Kindorf, Michigan Hanger, Power Strut, Unistrut, or approved equal. Anvil figure numbers are listed below; equivalent material by specified manufacturers is acceptable.
- B. Sleeves: Pipe Shields, Insul, RK Industries
- C. Pipe Wrap Tape: Polycen, Nassua, 3M
~~D.Firestop: Nelson, Dow, 3M, Hilti~~
- D. Escutcheon Plates: Beaton & Corbin Manufacturing
- E. Mechanical Sleeve Seals: Pipeline Seal and Insulator, Thunderline Linkseal, Calpico Pipe Linx, Metraflex Metraseal

2.02 GENERAL

- A. Provide hangers of heavy construction suitable for the size of pipe to be supported. Materials shall be of steel, except pipe rolls of wrought or malleable iron.
 1. Hangers for pipes six-inches or less shall be swivel ring, wrought pipe clamp, or

- adjustable wrought clevis type. Anvil Figures 65 or 260.
2. Hangers for pipes 8 inches and above shall have 2 rods and cross-rod with cast iron pipe roll complete with adjustable sockets and nuts. Anvil Figure 177, Anvil Figure 181 for steam piping.
 3. Pipe roller for all sizes of multiple horizontal steam piping 20 feet or longer, supported on a trapeze: MSS SP-58, Type 44.
- B. Multiple or trapeze pipe hangers shall be steel channels with welded spacers and hanger rods if hanger load calculations are submitted.
- C. Wall support shall be welded steel bracket with hanger. B-Line 3068 Series, Anvil Figures 194, 195 or 199.
1. Provide perforated epoxy painted finish, 16 - 12-gauge minimum steel channels securely anchored to wall structure with interlocking, split type, bolt-secured, galvanized pipe/tubing clamps. B-Line type S channel with B-2000 series clamps, Power-Strut Type PS200 H with PS 1200 clamps or equal.
 2. When copper piping is being supported, provide flexible elastomeric/thermoplastic isolation cushion material to completely encircle the piping and avoid contact with the channel or clamp, equal to B-Line B1999 Vibra Cushion, or provide manufacturers clamp and cushion assemblies, B-Line BVT series, Power-Strut PS 004T – PS 106N Series or equal.
- D. Support vertical piping with carbon steel double bolt riser clamps attached to the pipe. In general, use one clamp for each two floors and one clamp at each floor for copper tubing. Where pipes are in open shafts, provide forged steel bar brackets fixed to wall. Riser clamps shall be copper plated when used with copper pipe. Anvil Figure 261 for steel pipe, Anvil Figure CT121 for copper pipe.
- E. Floor Support for Pipe:
1. Sizes up to 4 inches: Cast iron adjustable pipe saddle, locknut nipple, floor flange, and concrete pier or steel support. Anvil Figure 264.
 2. Sizes 5 inches and over: Adjustable cast iron roll and stand, steel screws, and concrete pier or steel support. Anvil Figure 265.
 3. Provide pipe stanchions for support of pipe elbows at base of riser and vertical piping. Stanchions shall be complete with base plate and vent hole. Anvil Figures 62 and 63.
- F. Select hangers and supports in accordance with the manufacturer's recommended maximum loading. Hangers shall have a safety factor of 5 of 1.
- G. Hangers shall not be disengaged by movement of supported pipe.
- H. Provide copper plated or felt lined hangers for copper piping or provide 10-mil pipe wrap tape on pipe at hangers. Tape shall extend a minimum of 2 inches beyond hanger saddle on both ends and be wrapped around pipe a minimum of 2 turns. Install vinyl-coated hangers for all plastic piping.
- I. Steel hanger rods shall be threaded both ends, threaded one end, or continuous threaded, black finish. Provide rods complete with adjusting and lock nuts. Anvil Figures 146, 140 or 253
- J. Pipe Support Recommendations for Rigid Grooved Joint Systems: The maximum hanger spacing in the specification to ANSI B31 or NFPA as noted and should be used only in conjunction with Victaulic 07 zero-flex rigid couplings. For flexible systems the hanger, support, spacing and location refer to the pipe support recommendations section in the Victaulic "Field Assembly and Installation Pocket Handbook" or equivalent provided by Grooved Joint Manufacturer.

- K. Beam Clamps:
1. Provide MSS SP-69 Type 23 malleable black iron clamp for attachment to beam flange up to 0.62 inches thick for single threaded rods of 3/8, 1/2, and 5/8-inch diameter, for use with pipe sizes 4-inch and less. Furnish with a hardened steel cup point set screw. Anvil Figure 86.
 2. Provide MSS SP-69 Type 28 or Type 29 forged steel jaw type clamp with a tie rod to lock clamp in place, suitable for rod sizes up to 1½-inch diameter but limited in application to pipe sizes 8-inch and less without prior approval. Anvil Figure 228.
- L. Continuous Concrete Insert Channels:
1. Provide steel inserts with industry standard pre-galvanized finish, nominally 1-5/8-inch wide by 1-3/8-inch deep by length to suit the application, designed to be nailed to concrete forms and provide a linear slot for attaching other support devices.
 2. Installed channels shall provide a load rating of 2000 pounds per foot in concrete. Manufacturer's standard brackets, inserts, and accessories I inserts are acceptable.
 3. Select insert length to accommodate all pipe, duct, and conduit in the area.
- M. Anchors shall be fabricated using welding steel shapes, plates, and bars to secure piping to the structure.
- N. Concrete inserts shall be MSS SP-69 Type 18 wedge type or universal concrete inserts.
1. Wedge type shall be constructed of a black carbon steel body with a removable malleable iron nut that accepts threaded rod to 7/8-inch diameter. Wedge design shall allow the insert to be held by concrete in compression to maximize the load carrying capacity. Anvil Figure 281.
 2. Universal type shall be constructed of black malleable iron body with a removable malleable iron nut that accepts threaded rod to 7/8-inch diameter. Anvil Figure 282.
 3. Use drilled steel shell with plug type inserts when the inserts are placed after the concrete is poured.
- O. Drainage Piping: Provide MSS Type 8 or MSS Type 42 riser clamps for vertical piping, and MSS Type 52, spring hangers at the base of vertical piping.

2.03 SLEEVES

- A. Construct sleeves for pipes passing through walls (other than foundation walls), floors, partitions, hung or furred ceilings, etc., of minimum 18-gauge galvanized steel, flanged on each side of wall, partition, hung or furred ceiling, etc.
- B. Provide standard weight galvanized steel pipe sleeves with welded anchor flanges at foundation walls and reinforced concrete or masonry walls.
- C. Provide 20-gauge galvanized sheet metal sleeves, the full depth of floor or wall, for round ductwork passing through masonry or concrete and/or steel cellular floor construction. Rectangular ductwork shall be provided with framed openings through floor and wall construction.
- D. Provide cast iron or fabricated "wall pipe" equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.
- E. Stack Sleeve Fittings: Provide manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring, bolts, and nuts for membrane flashing and underdeck clamping ring with setscrews.
- F. Provide mechanical sleeve seals at exterior wall and tank wall penetrations. Seal shall be of the modular sealing element unit type, designed for field assembly, to fill annular space

between pipe and sleeve.

1. Sealing Elements: ~~{EPDM}~~ ~~{NITRILE}~~ ~~{SILICONE}~~ interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
 2. Pressure Plates: ~~{Plastic}~~ ~~{Carbon steel with corrosion-resistant coating}~~. Include two for each sealing element.
 3. Connecting Bolts and Nuts: ~~{Carbon steel with corrosion-resistant coating}~~ ~~{Stainless steel}~~ of length required to secure pressure plates to sealing elements. Include one for each sealing element.
- G. Install escutcheons at exposed piping through floors, ceilings, walls and partitions in finished areas, within cabinets and millwork, and piping through all fire-rated separations. Provide manufactured wall and ceiling escutcheons and floor plates, with an inside diameter to closely fit around pipe, tube, and insulation of insulated piping and an outside diameter that completely covers opening. Escutcheons shall be cast iron or cast brass, deep-pattern escutcheons if required to conceal protruding fittings, sleeve hubs or firestopping projections.

2.04 PENETRATION FIRESTOP

~~A. Fire-Rated Construction: Maintain barrier and structural floor fire resistance ratings including resistance to cold smoke at all penetrations, connections with other surfaces or types of construction, and sound or vibration absorption, and at other construction gaps.~~

~~B. Smoke Barrier Construction: Maintain barrier and structural floor resistance to cold smoke at all penetrations, connections with other surfaces and types of construction and at all separations required to permit building movement and sound or vibration absorption, and at other construction gaps.~~

~~C. Systems or devices listed in the UL Fire Resistance Directory under categories XHCR and XHEZ may be used, providing that it conforms to the construction type, penetrant type, annular space requirements and fire rating involved in each separate instance, and that the system be symmetrical for wall applications. Systems or devices must be asbestos-free. Mortar systems must be Warnock Hersey approved.~~

~~D. Withstand the passage of cold smoke either as an inherent property of the system, or by the use of a separate product included as a part of the UL system or device, and designed to perform this function.~~

~~E. All firestopping products must be from a single manufacturer.~~

~~F. Through-penetration smoke stopping at smoke partitions: Any system complying with the requirements for through-penetration firestopping in fire-rated construction, as specified, is acceptable, provided that the system includes the specified smoke seal or will provide a smoke seal. The length of time of the fire resistance may be disregarded in a non-fire-rated smoke barrier.~~

~~G. Seal all pipe and duct penetrations through fire-rated construction with factory built devices or with manufactured fill, void, or cavity materials "Classified" by Underwriters Laboratories, Inc. for use as a Through-Penetration Firestop. All firestop devices and systems shall be approved for such use by the authority having jurisdiction. The firesafing system used shall maintain the fire resistance rating of the building component that is penetrated.~~

~~H. All materials shall be non-hardening and non-toxic. The firesafing system used shall accommodate expansion and contraction of the floating mechanical piping systems without damaging the firestop or reducing its effectiveness as a smoke barrier or water seal.~~

2.04 GROUT

- A. Grout shall be slow-hardening after application, volume-adjusting, nonstaining, noncorrosive,

nongaseous, and recommended for interior and exterior applications.

- B. Provide ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.
- C. Design Mix: 5000 psi, 28-day compressive strength from a premixed and factory pre-package.

PART 3 – EXECUTION

3.01 HANGERS AND SUPPORTS

- A. Deflection of pipes shall not exceed 1/240th (0.416 percent) of span. Support horizontal piping in accordance with the following schedule:

| Pipe Size (inches) | Maximum Hanger Spacing (feet) | | | | | | | | Hanger Rod Diameter (inches) | | |
|-----------------------|-------------------------------|--------------|--------|---------|-----|------|------|----|---------------------------------|--------|---------|
| | Steel | Cast Iron | Copper | Plastic | | | | | Steel/ Cast Iron | Copper | Plastic |
| | | | | CPVC | PVC | PP | PVDF | FG | | | |
| up to 1 | 7 | -- | 5 | 3.5 | 3 | 2.75 | 2.5 | 10 | 3/8 | 3/8 | 3/8 |
| 1¼ | 9 | -- | 7 | 3.5 | 3 | 2.75 | 3 | 10 | 3/8 | 3/8 | 3/8 |
| 1½ & 2 | 9 | 5 | 8 | 3.5 | 3.5 | 2.75 | 3 | 10 | 3/8 | 3/8 | 3/8 |
| 2½ | 12 | 5 | 9 | 3.5 | 3.5 | 3.5 | 3.5 | 10 | 1/2 | 1/2 | 1/2 |
| 3 | 12 | 5 | 10 | 3.5 | 3.5 | 3.5 | 3.5 | 10 | 1/2 | 1/2 | 1/2 |
| 3½ | -- | 5 | 11 | -- | -- | -- | -- | -- | 5/8 | 1/2 | -- |
| 4 | 12 | 5 | 12 | 4 | 4 | 4 | 4 | 10 | 5/8 | 1/2 | 5/8 |
| 5 | 12 | 5 | 13 | 4 | 4 | 4 | 4 | 10 | 5/8 | 1/2 | 5/8 |
| 6 | 12 | 5 | 14 | 4 | 4 | 4 | 4 | 10 | 3/4 | 5/8 | 3/4 |
| 8 to 12 | 12 | 5 | 14 | -- | 4 | 4 | -- | 12 | 7/8 | 3/4 | 7/8 |
| 14 & 16 | 12 | 5 | -- | -- | -- | -- | -- | -- | 1 | -- | -- |
| 18 & 20 | 12 | -- | -- | -- | -- | -- | -- | -- | 1¼ | -- | -- |
| 24 | 12 | -- | -- | -- | -- | -- | -- | -- | 1½ | -- | -- |

(C) PVC: (Chlorinated) Polyvinyl Chloride Plastic; PP: Polypropylene plastic; PVDF: Polyvinylidene Fluoride Plastic; FG: Fiberglass

- B. Provide hangers at each change in direction and both sides of valves 4-inch and larger. Place a hanger within 12 inches of each horizontal elbow, valve, strainer, or similar piping specialty item.
- C. Support hangers from concrete inserts or beam clamps. Furnish, locate and set inserts. Construct inserts of malleable iron or pressed steel with space for rods of all sizes. Install inserts for pipes 3 inches and larger in size with a reinforcing rod 5/8-inch in diameter run through a slot in the insert specifically provided for this purpose.
- D. If piping is required in a space where no inserts have been provided, drill holes in the slab (subject to structural engineer's prior approval) and provide rods and hanger attached to an approved fishplate or install double expansion shields connected by a 2-inch by 2-inch angle, from which the hanger rod is to be suspended. For pipe size 2 inches and under use single shields but the hanger spacing shall be reduced to 5 feet. The carrying capacity and size of

each shield shall be calculated on the basis of the spacing indicated above but the minimum size shall be 3/8-inch. Install additional shields of the same size so that the number of hangers is of adequate size to support the loads, which they carry. Shields may be used in concrete slabs only. Obtain from the expansion shield manufacturer an ICBO Evaluation Report for the product and submit to the Architect.

- E. Regardless of the type of construction (i.e., concrete, concrete-deck-steel or other variations) take particular care to support main lines and large and heavy pipes in an approved manner, including the provision of supplementary steel, if required. Supplementary steel shall be mill-rolled sections. Submit shop drawings, indicating support methods, point loadings to the building structure and hanger locations for review sufficiently in advance of concrete pouring schedules to permit evaluation, critique and any necessary changes to handling and support methods.
- F. Hangers shall be directly bolted to steel beams of building construction, where they occur if approved by the structural engineer. Smaller pipes shall be suspended from crosspieces of pipe or steel angles, which in turn, are securely fastened to building beams or hung from building concrete construction by means of rods and inserts. The intention is to provide supports which shall be amply strong and rigid for the load, but which will not weaken or unduly stress the building construction.
- G. Attachments to existing steel deck shall be limited to loads of 500 pounds. Heavier loads shall be supported by supplementary structural steel connected to structural beams. Provide all required supplementary steel.
 - 1. Attachments with loads up to 500 pounds shall be accomplished by drilled-in expansion shield type anchors located on the centerline of the concrete filled ribs.
 - 2. No attachments shall be permitted to new or existing electrified decks. If hanger attachments are not existing, all new attachments shall be supported from supplementary steel.
 - 3. 500-pound load attachments shall be spaced not less than 60 inches apart, and shall be located as close to steel beams as possible.
- H. Provide approved roller support, floor stands, wall brackets, etc., for lines running near the floor or near walls, which can be properly supported or suspended by the floors or walls. Pipelines near walls may also be hung by hangers carried from approved wall brackets at a higher level than the pipe.
- I. Do not hang piping or ductwork from supports for other services. Installed supports shall accommodate free expansion of the piping and duct system.
- J. Wherever hangers using pipe rolls are used, provide approved steel pipe covering protection saddles, spot-welded to the piping at each hanger location.
- K. Anchor piping where shown to localize expansion or to prevent undue strain on piping and branches. Anchors shall be entirely separate from hangers and of heavy forged or welded construction of approved design. All anchor designs, when submitted for approval, shall include piping reactions which respective anchors are capable of supporting. Provide indicated expansion loop.
- L. Install anchors where indicated on the drawings and details. Where not specifically indicated, install anchors at ends of principal pipe runs and at intermediate points in pipe runs between expansion loops. Make provisions for preset of anchors as required to accommodate both expansion and contraction of piping.
- M. Support copper tubing individually by approved hangers not more than 6 feet apart. Hangers for uncovered lines shall be specially designed for copper tubing and of exact outside diameter of tubing. Hangers for covered tubing shall be broad straps fitting outside of covering.

- N. Hangers for insulated piping shall support the pipe without piercing the insulation. Refer to Section 23 07 00 - Insulation for insulation protection shields and pipe inserts.
- O. For piping 4 inches and larger, support the elbows of the piping adjacent to pumps with steel supports from the concrete housekeeping pad, or from the inertia base where pump is mounted to prevent loading heavy weights of piping on pump flanges or casing. Where inertia base or spring vibration isolation is not provided, base elbows shall be supported on concrete pad with 1-inch neoprene pad.
- P. Use hangers, which are vertically adjustable 1½-inch minimum after piping is erected. Install hangers so that ½-inch minimum clearance is maintained between finished covering of pipe and adjacent work.
- Q. Support riser piping independently of connected horizontal piping.
- R. Adjust hangers to obtain pipe slope where specified.
- S. Where piping can be conveniently grouped to allow the use of trapeze type supports, use standard structural shapes or continuous insert channels for the supporting steel. Where continuous insert channels are used, pipe supporting devices made specifically for use with the channels may be substituted for the specified supporting devices provided that similar types are used and all data is submitted for prior review.
- T. Perform all welding in accordance with standards of the American Welding Society. Clean surfaces of loose scale, rust, paint or other foreign matter and properly align before welding. Use wire brush on welds after welding. Welds shall show uniform section, smoothness of weld metal and freedom from porosity and clinkers. Where necessary to achieve smooth connections, joints shall be dressed smooth
- U. Factory coat supports and anchors used in corrosive atmospheres with hot dip galvanizing after fabrication, ASTM A123, 1.5-ounces/square foot of surface, each side. Mechanical galvanize threaded products, ASTM B695 Class 150, 2.0 mil coating. Field cuts and damaged finishes shall be field-covered with zinc rich paint of comparable thickness to factory coating. Corrosive atmospheres include the following locations:
 - 1. Exterior locations, parking ramps, carwash areas
 - 2. Swimming pool equipment, chemical storage or hazardous waste storage rooms
 - 3. Wet wells, meter pits
 - 4. Sanitary and storm sewer pumping stations
 - 5. Food service/kitchen areas, walk-in coolers/freezers
 - 6. Locker/shower rooms
 - 7. Greenhouses

3.02 SLEEVES

- A. Provide sleeves for pipe passing through floors, walls or partitions, hung or furred ceilings, of sufficient diameter to accommodate pipe covering where such is required. Locate sleeves secure in place so that an equal space is around the pipe, after the pipe is installed.
- B. For sleeves at penetrations of metal deck, nail, screw or weld to the deck prior to the pouring of the deck concrete. Set sleeves in such a manner so that no concrete fills their interior during the concrete pouring and finishing operations.
- C. For exposed pipes, caulk floor sleeves with firestop material watertight and project sleeve approximately 2 inches above the finished floor. Finish sleeves with specified flanges flush with the bottom of slab and also with the finished faces of wall.
- D. Provide sleeves with an inside diameter at least ½-inch greater than outside of pipe served, including pipe insulation which must be continuous through sleeve.

- E. Where piping penetrates walls (other than foundation walls), partitions, floor slabs, etc., pack space between piping and sleeve with mineral wool (for depth of sleeve), or firestop material.
- F. Do not support pipes by resting clamps on sleeves. Clamps shall extend beyond sleeve and be supported outboard of sleeve in an approved manner. In no case shall sleeves be cut or slotted to accommodate pipe clamps.
- G. Provide escutcheon plates of the proper size for piping in sleeves passing through floors, walls, soffits, furrings, partitions, hung ceilings, etc., throughout the building where exposed. Exposed escutcheons shall be cast brass chromium plated, bell type, with setscrews of sufficient diameter to include any required pipe insulation. Attach escutcheon to building material, not to pipe. Do not penetrate vapor barriers.
 - 1. Split-casting, deep-pattern type cast-brass type with concealed hinge and set screw with polished chrome-plated and rough brass finish.
 - 2. Split-casting, floor-plate type cast brass with concealed hinge and setscrew.
- H. Exterior-wall pipe penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
 - 1. Install aboveground steel pipe for sleeves smaller than 6 inches.
 - 2. Install aboveground cast-iron "wall pipes" for sleeves 6 inches and larger.
 - 3. Install underground cast-iron "wall pipes" for all sleeves.
 - 4. Mechanical Sleeve Seal Installation:
 - a. Select type and number of sealing elements required for pipe material and size.
 - b. Position pipe in center of sleeve.
 - c. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve.
 - d. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.
 - e. For wall thickness up to 12 inches provide one mechanical sleeve seal at the interior side of sleeve, for wall thickness greater than 12 inches provide two mechanical sleeve seals, one at the interior side of sleeve and one at the exterior side of sleeve.

3.03 FIRESTOPPING

- A. Where space for future ducts, pipes and conduits is required, provide sleeves and fill with lightweight concrete or firestop.
- B. Provide firestopping and grouting around pipes and ducts penetrating concrete slabs, concrete walls and masonry walls with cement grout in the sleeved opening extending full depth through wall or floor slab. Provide sheet metal cover over the insulation before applying grout. Around pipes and ducts through fire rated gypsum board construction, pack the annular space between the wall sleeve and the insulation sheet metal cover with noncombustible approved firestop material and finish with 20-gauge sheet metal collar on ducts and escutcheons on pipe where duct or pipework is exposed. Attach escutcheons to wall.
- C. Verify existing conditions and substrates before starting work. Correct unsatisfactory conditions before proceeding. Proceed with installation only after penetrations of the substrate and supporting brackets have been installed.
- D. Environmental Requirements:
 - 1. Provide adequate ventilation if using solvent.

2. Provide forced air ventilation during installation if required by manufacturer.
 3. Keep flammable materials away from sparks or flame.
 4. Provide masking and drop cloths to prevent contamination of adjacent surfaces by firestopping materials.
 5. Comply with manufacturing recommendations for temperature and humidity conditions before, during and after installation of firestopping.
- E. Clean surfaces that will be in contact with penetration seal materials of dirt, grease, oil, loose materials, rust, or other substances that may affect proper fitting, adhesion, or the required fire resistance.
- F. Install penetration seal materials in accordance with the U.L. Fire Resistance Directory or Mortars per Warnock Hersey approval and in accordance with manufacturer's instruction.
- G. Seal holes or voids made by penetrations to ensure an effective smoke barrier.
- H. Where large openings are created in walls or floors to permit installation of pipes, ducts or other items, close unused portions of opening with firestopping material tested for the application. See UL Fire Resistance Directory or Warnock Hersey approvals.
- I. Install smokestopping as specified for firestopping.

3.04 GROUTING

- A. Mix, install and cure grout for mechanical equipment base bearing surfaces, pump and other equipment base plates, and anchors.
- B. Clean surfaces that will come into contact with grout. Provide forms as required for placement of grout. Avoid air entrapment during placement of grout.
- C. Place grout, completely filling equipment bases.
- D. Place grout on concrete bases and provide smooth bearing surface for equipment.
- E. Place grout around anchors.

END OF SECTION

VIBRATION ISOLATION AND SEISMIC RESTRAINTS

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to the following:
1. Vibration isolation elements for mechanical piping, ductwork and rotating equipment
 2. Equipment isolation bases
 3. Flexible connectors
 4. Seismic restraints for isolated and non-isolated equipment, piping and ductwork
 5. Supervision and inspection of installed vibration isolators, seismic restraints, anchorage and associated hardware

1.02 SUBMITTALS

- A. Manufacturer's Data:
1. Catalog cuts and data sheets on specific vibration isolators to be utilized showing compliance with the specifications.
 2. An itemized list showing the items of equipment and piping to be isolated, the isolator type and model number selected, isolator loading and deflection, and reference to specific drawings.
 3. Written approval of the base design shall be obtained from the equipment manufacturer.
- B. Shop Drawings: Concrete reinforcing details and templates for all foundations, bases, supports, inertia blocks, hanger bolts, etc.; support frame details, pipe support details; vibration isolation mountings for equipment and piping including equipment weight, center of gravity and operating speed, location and installation details. Include in the vibration isolation equipment submittal drawing the following information based on equipment submittals released for construction.
1. Isolation mounting deflections.
 2. Spring diameters, compressed spring heights at rated load and solid spring heights where steel spring isolation mountings are used.
 3. Equipment operating speed.
 4. Seismic restraint calculations stamped by a California State licensed structural or civil engineer.
 5. Product data and current OSHPD certification OPA number verifying that the system is currently pre-approved by OSHPD or provide calculations to demonstrate compliance with the requirements of regulatory agencies.
 6. Note compliance with seismic code regulations and the project specification on the submittals.
 7. Number and location of seismic restraints and anchors for each piece of equipment including but not limited to bolted or welded connections between cooling tower and support beams, vertical pipe risers, bolt sizing and embedment depth, and seismic cable strength and diameters.
 8. Specific details of restraints including anchor bolts for mounting and maximum loading at each location.
 9. Drawings showing methods of suspension, support guides for piping and ductwork.
 10. Drawings showing methods of isolation of pipes and ductwork piercing walls and floor slabs.
 11. Provide installation instructions, drawings and field supervision to assure proper installation and performance.

1.03 REFERENCE STANDARDS

A. Published specifications standards, tests or recommended methods of trade, industry or governmental organizations apply to work in this section where cited below:

1. IBC – International Building Code

1.04 MANUFACTURER RESPONSIBILITIES

A. Manufacturer of vibration isolation equipment shall have the following responsibilities:

1. Determine vibration isolation and seismic restraint sizes and required locations.
2. Provide piping, ductwork and equipment isolation systems and seismic restraints as scheduled or specified.
3. Guarantee specified isolation system deflection.
4. Provide installation instructions, drawings and field supervision to assure proper installation and performance.
5. Seismic restraints shall be designed for the lateral and vertical forces required by the Building Code for the specific project type and site. Confirm lateral force assumptions with the project structural engineer.

1.05 QUALITY ASSURANCE

A. Provide control of excessive noise and vibration in the buildings due to the operation of machinery or equipment, and/or due to interconnected piping, ductwork or conduit. Install vibration isolation units and associated hangers and bases under the direct supervision of the vibration isolation manufacturer's engineer.

1. Vibration isolators shall have either known undeflected heights or calibration markings so that after adjustment, when carrying their load, the deflection under load can be verified, thus determining that the load is within the proper range of the device and that the correct degree of vibration isolation is being provided according to the design.
2. Isolators shall operate in the linear portion of their load versus deflection curve. Furnish load versus deflection curves that are linear over a deflection range of not less than 50% greater than the design deflection.
3. The ratio of lateral to vertical stiffness shall be neither less than 0.9 nor greater than 1.5.
4. The theoretical vertical natural frequency for each support point, based upon load per isolator and isolator stiffness shall not differ from the design objectives for the equipment as a whole by more than plus or minus 10%.
5. All neoprene mountings and components shall be oil resistant and have:
 - a. Shore durometer hardness of 40 to 65, after minimum aging of 20 days or corresponding oven-aging
 - b. Minimum tensile strength of 2000 pounds per square inch
 - c. Minimum elongation of 300%
 - d. Maximum compression set at 25%

B. Mounting systems or components shall not be resonant with any of the supported equipment forcing frequencies.

C. Isolators shall be selected on the basis of the static and dynamic loads actually supported. Dynamic loads include those due to: wind, fluid flow, thrust and rotational inertia. Select each isolator independently for proper load distribution on each piece of equipment, duct and pipe support, or base.

D. Vibration Isolation Hardware shall not be concealed until reviewed by the Architect.

- E. Verify specified clearances, plumb installation of hanger rods and lack of interference – no contact permitted with gypsum board, framing, ceiling wires, light fixtures, conduit, ducts and piping.
- F. Verify that the space below inertia bases is clean and clear of construction debris and obstructions.
- G. Verify proper vibration isolator loading and deflection.
- H. Vibration isolation field inspection engineer shall provide a punchlist report for the Architects review.
- I. Vibration isolation field inspection engineer shall submit a closeout letter stating that the installation is complete and meets the requirements of the specification and the manufacturer's installation instructions.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Vibration Isolation: Mason Industries (MII), Vibration Mountings & Control (VMC), Amber-Booth (AB), Vibration Eliminator (VEC), Vibrex Vibration Control Systems (VVC)
- B. Piping and Duct Seismic Bracing: Kin-Line, Super Strut, Mason Industries

2.02 MATERIALS

- ~~A. Provide products with current OSHPD certification OPA numbers or products furnished with calculations demonstrating compliance.~~
- A. All vibration isolation devices shall be the products of a single manufacturer.
- B. Where exposed to the atmosphere all steel shall be hot dipped galvanized; hardware shall be cadmium plated; springs shall be powder coated.

2.03 VIBRATION ISOLATORS

- A. Refer to these specifications and drawings for vibration isolator types to be used:
 - 1. Type A spring isolators shall incorporate the following:
 - a. Minimum diameter of 0.8 of the loaded operating height and horizontal spring stiffness 1.1 times rated vertical spring stiffness.
 - b. Reserve deflection, from loaded to solid height, of 50% of rated deflection with leveling device.
 - c. Minimum ½-inch thick neoprene acoustical base pad on underside, unless designated otherwise. Neoprene elements shall be as specified.
 - d. Designed and installed so that ends of springs remain parallel.

| | |
|----------------|-----|
| Type SLF..... | MII |
| Type OSK..... | VEC |
| Type RMS | VMC |
 - 2. Type B spring isolators shall similar to Type A, except inherently restrained:
 - a. Provide built-in resilient vertical limit stops with neoprene grommets.
 - b. Tapped holes in base plate for bolting isolator to base, housekeeping pad or

- c. structural support. Tapped holes in top plate for bolting to equipment. Capable of supporting equipment at fixed elevation during equipment erection.

Type SLR Series 100 MII
 Type KW VEC
 Type RMSL-EQ VMC

3. Type C spring hanger rod isolators shall incorporate the following:

- a. Spring element seated on a steel washer in series with a deflected neoprene element as specified.
- b. Steel retainer box encasing the spring and neoprene washer. Ensure no metal-to-metal contact.
- c. Minimum 1/2-inch clearance between retainer box and spring hanger rod. Provide neoprene grommet.
- d. Maximum 30° allowable rod misalignment from centerline axis.

Type 30N MII
 Type SNCR VEC
 Type RSH-30A VMC

4. Type C1 precompressed spring hanger rod isolators shall incorporate the following:

- a. Spring element seated on a steel washer in series with a deflected neoprene element as specified.
- b. Steel retainer box encasing the spring and neoprene washer. Ensure no metal-to-metal contact.
- c. Minimum 1/2-inch clearance between retainer box and spring hanger rod. Provide neoprene grommet.
- d. Where operating weight differs from installed weight provide built-in adjustable limit stops to prevent equipment rising when weight is removed. Stops shall not be in contact during normal operation. Clearly indicate deflection with scale on isolator.
- e. Maximum 30° allowable rod misalignment from centerline axis.

Type PC30N MII
 Type SNCR VEC
 Type RSH-30A VMC

5. Type D elastomer inherently restrained isolators shall incorporate the following:

- a. Bolt holes for bolting to equipment base.
- b. Bottom steel plates for bolting to sub-base as required.
- c. Molded unit type neoprene element as specified.

Type BR MII
 Type 368 SD VEC
 Type FUD-EQ VMC

6. Type E elastomer hanger rod isolators shall incorporate the following:

- a. Molded unit type neoprene element as specified.
- b. Steel retainer box encasing neoprene mounting.
- c. Clearance between mounting hanger rod and steel retainer box. Provide neoprene grommet.

Type HD MII
 Type CD VEC

Type HSS..... VMC

- 7. Type F pad type elastomer mountings shall incorporate the following:
 - a. 3/4-inch minimum thickness neoprene elements as specified. Verify thickness will not degrade or derate the isolator performance.
 - b. Sized for 50 pounds per square inch maximum loading. Provide suitable bearing plate to distribute load.
 - c. Ribbed or waffled design.
 - d. 1/6-inch deflection per pad thickness.
 - e. 16 gauge galvanized steel plate between multiple layers of pad thickness.

Type Super WMSW MII
 Type 200N..... VEC
 Type Iso-Cube..... VMC

- 8. Type G pad type elastomer mountings shall incorporate the following:
 - a. Neoprene impregnated canvas duck material.
 - b. Maximum loading 1000 pounds per square inch. Provide suitable bearing plate to distribute load.
 - c. Minimum thickness, 2-inch.

Type HL..... MII
 Type Fabriflex VMC

- 9. Type H: Rooftop equipment spring isolation curb shall incorporate the following:
 - a. The lower member shall consist of a sheet metal Z section containing adjustable and removable steel springs that support the upper floating section. The upper frame must provide continuous support for the equipment and must be captive so as to resiliently resist wind and seismic forces. All directional neoprene snubber bushings shall be a minimum of 1/4 inch thick. Steel springs shall be laterally stable and rest on 1/4 inch thick neoprene acoustical pads.
 - b. The curbs waterproofing shall consist of a continuous galvanized flexible counter flashing nailed over the lower curbs waterproofing and joined at the corners by EPDM bellows. All spring locations shall have access ports with removable waterproof covers. Lower curbs shall have provision for 2-inch thick insulation.
 - c. The roof curbs shall be built to seismically contain the rooftop unit. The unit must be solidly fastened to the top floating rail, and the lower Z section anchored to the roof structure. Curb shall have anchorage pre-approval "OPA" from OSHPD in the state of California attesting to the maximum certified horizontal and vertical load ratings.

Type SRSC MII

- 10. Type I: Provide diagonal thrust restraint consisting of Type A isolator with the same deflection as specified for the spring mountings. Design the spring element so it can be preset for thrust and adjusted to allow for a maximum of 1/4-inch movement at start and stop. Attach diagonal restraints at the centerline of thrust restraint.

Type WBI or WBD..... MII

2.04 EQUIPMENT BASES

- A. Structural Steel Base, Type B-1:

1. Reinforce base as required to prevent flexure at start-up and misalignment of drive and driven units. Provide centrifugal fan bases complete with motor slide rails, drilled or slotted for drive and driven unit mounting template with height saving brackets and equipment bolting provisions.
2. A minimum operating clearance of 2 inches shall exist between the inertia base and the housekeeping pad.

Type WF or M..... MII

B. Concrete Inertia Base, Type B-2:

1. Concrete inertia bases shall be formed in a structural steel perimeter base, reinforced as required to prevent flexure, misalignment of drive and driven unit or stress transfer into equipment. The base shall be complete with pump or piping base elbow support anchors and complete with height saving brackets, reinforcing, equipment bolting provisions.
2. Each pump with its driving motor shall be bolted and grouted to a spring-supported concrete inertia base reinforced as required. Provide a minimum of four spring vibration isolators as specified and/or shown on Drawings.
3. Each rectangular concrete base (or "T" shaped for horizontally split-case pumps) shall include supports and base elbows for pump suction and discharge connections. Base elbows shall be bolted and grouted to the concrete foundation.
4. The suction and discharge pipe elbows of horizontal and/or vertical inline pumps shall be provided with welded vertical support stanchions of adequate strength and rigidity. These support stanchions along with the pump supports shall be bolted and grouted to a concrete inertia base, which in turn shall be supported on steel spring isolators. A minimum operating clearance of 2 inches shall exist between the inertia base and the housekeeping pad.

5. Minimum thickness of the inertia base shall be as follows:

| Motor Size (Horsepower) | Minimum Thickness (Inches) |
|-------------------------|----------------------------|
| 5-15 | 6 |
| 20-50 | 8 |
| 60-75 | 10 |
| 100-250 | 12 |

Type K or BMK MII

2.05 FLEXIBLE PIPING CONNECTORS

A. Neoprene Type FC-1:

1. Manufactured of kevlar tire cord and neoprene molded and cured with hydraulic presses.
2. Straight connectors shall have two spheres.
3. Elbow shall have single sphere forming the corner of joint.
4. Rated 150 pounds per square inch at 220° F.

Type Safeflex SFDEJ, SFDCR MII

B. Flexible Stainless Hose, Type FC-2:

1. Braided flexible metal hose.
2. 2-inch pipe size and smaller with male nipple fittings.
3. 2½-inch and larger pipe size with fixed steel flanges.
4. Suitable for operating pressure and temperature with 4:1 minimum safety factor.
5. Length as specified on Drawings.

Type BSS MII

Type MFP VMC

2.06 SEISMIC RESTRAINTS

A. General:

1. Provide restraints capable of safely accepting forces specified in Part 1 of this section, without failure, to maintain equipment, piping, and ductwork in a captive position. Restraints must not short circuit vibration isolation systems or transmit objectionable vibration or noise. Submit calculations by Structural Engineer licensed and registered in the State of the project to verify seismic restraint and cable capacities. [Provide products with current OSHPD certification OPA numbers or provide calculations demonstrating compliance with regulatory requirements.]

- a. Seismic Restraint, Type I: All directional seismic snubbers shall consist of interlocking steel members restrained by molded neoprene bushing compounded to bridge bearing specifications. Bushing shall be replaceable and a minimum of 1/4 inch thick. Rated loadings shall not exceed 1000 psi. Snubbers shall be manufactured with an air gap between hard and resilient material of not less than 1/8 inch or more that ¼ inch. Snubbers shall be installed with factory set clearances. The capacity of the seismic snubber at 3/8 inch deflection shall be equal or greater than the load assigned to the mounting grouping controlled by the snubber multiplied by the applicable "G" force. Submittals shall include the load deflection curves up to ½ inch deflection in the x, y and z planes. ~~Snubbers shall have an anchorage pre-approval "OPA" number from OSHPD in the state of California verifying the~~

Type Z-1225-1 MII

- b. Seismic Restraint, Type II: Cable type with approved end fastening devices (minimum of two per end) to equipment and structure. Cable to comply with Federal Specification MIL-W-83420 military grade 7x19 galvanized steel.

Type SCBH MII

- c. Seismic Restraint, Type III: Seismic solid braces shall consist of steel angles or channels to resist seismic loads with a minimum safety factor of 2 and arranged to provide all directional restraint. Seismic solid brace end connectors shall be steel assemblies that swivel to the final installation angle and utilize two through bolts to provide proper attachment. [Seismic solid brace assembly shall have anchorage pre-approval number from OSHPD in the state of California verifying the maximum certified load ratings.]

Type SSBS MII

PART 3 – EXECUTION

3.01 GENERAL

- A. Install in accordance with manufacturer’s recommendations and written instructions. Vibration isolators must not cause any change of position of equipment or piping resulting in piping stresses or misalignment.
- B. Isolate mechanical equipment from the building structure by means of vibration isolators as specified and scheduled on the Drawings.
- C. Vibration isolated piping and ductwork shall pass freely through walls and floors without rigid connections. Maintain ¾-inch to 1¼-inch concentric clearance around outside surfaces of piping or ductwork at penetration points. Pack this clearance space tightly with fiberglass, and caulk airtight after installation of piping or ductwork, or provide resilient firestopping as required. Provide supports 6 to 8 inches from walls or partitions on both sides of penetrations.
- D. Do not make rigid connections between equipment and building structure that degrades or short circuits the vibration isolation system specified herein.
- E. Loop electrical circuit connections to isolated equipment to allow free motion. Include at least one slack 90° bend.
- F. Bring to the Architect’s attention prior to installation any conflicts with other trades, which will result in unavoidable rigid contact with equipment or piping as, described herein, due to inadequate space or other unforeseen conditions. Corrective work necessitated by conflicts after installation will be at the Contractor’s expense.
- G. Support vertical piping loads, including water strainers, and valves between pump base elbow supports and the suction and discharge header piping by means of the pump base spring isolators without stress or strain to the pump housing.
- H. Provide a flanged steel pipe spool piece between suction and discharge valves and pumps to permit future installation of flexible connectors.
- I. Level vibration isolated equipment under rated design operating conditions while maintaining the isolation criteria. Isolators shall be plumb and aligned during operation.

3.02 EQUIPMENT ISOLATORS

- A. Mount vibration isolating devices and related inertia blocks on concrete housekeeping pads.
- B. Support each fan and motor assembly on a single structural steel frame. Provide flexible duct connections at inlet and discharge of heat pumps, air conditioning units, fan coils and fans, including plug fan assemblies inside factory assembled air handling units unless prohibited by codes or local authorities having jurisdiction. Refer to Section 23 31 00, Ductwork.
- C. If the equipment to be mounted is not furnished with integral structural frames and external mounting lugs (both of suitable strength and rigidity), install approved structural sub-base in the field which will support the equipment to be hung and to which will be attached the hangers.

~~D. Provide cooling tower with sufficient bolted connections to structural steel support beam. Verify cooling tower mounting flange thickness and bolt hole diameters with seismic calculations.~~

D. Additional Requirements:

1. Provide brackets to accommodate the isolator. Manufacturer shall indicate bolt hole sizes and locations, welds required, and specify the vertical position and size of the bracket.
2. Maintain a minimum operating balance between the equipment frame on rigid steel base frame and the concrete housekeeping pad of 1 inch. Maintain a minimum operating clearance between concrete inertia and base and concrete housekeeping pad or floor of 2 inches.
3. Temporarily support the structural steel or concrete inertia base with blocks or shims, as appropriate, prior to the installation of the equipment or isolators.
4. Install the isolators without raising the equipment and frame assembly.
5. Adjust the isolators after the entire installation is complete and under full operational load so that the load is transferred from the blocks to the isolator. When all isolators are properly adjusted, the blocks or shims will be barely free and shall be removed.
6. Verify that all insulated isolator and mounting systems permit equipment motion in all directions. Adjust or provide additional resilient restraints to flexibly limit equipment start-up lateral motion to ½-inch.
7. Prior to start-up, clean out all foreign matter between bases and equipment and under inertia bases. Verify that there are no isolation short circuits in the base or isolators.

~~3.03 CONTROL AIR COMPRESSORS~~

~~A. Mount control air compressors up to 3 horsepower on Type B-1 structural steel base.~~

~~B. Mount control air compressors over 3 horsepower on Type B-2 concrete inertia base.~~

~~C. Provide Type A open spring vibration isolators between base and concrete housekeeping pad.~~

~~D. Provide Type FC-2 flexible hose at discharge connections of each compressor. Use two straight lengths with a 90° pipe elbow between each to provide flexibility in all directions.~~

3.04 PIPING ISOLATORS

A. Isolate piping as follows:

- ~~1. Piping in machine rooms, fan rooms, or boiler rooms~~
- ~~2. Piping within 50 feet (or 100 diameters if greater) from connected rotating equipment and pressure reducing stations~~
- ~~3. As additionally specified in the following clauses.~~

- ~~B. Install isolators with the isolator hanger box attached to, or hung as close as possible to, the structure. Provide outrigger supports where required for clearance to equipment and to maintain minimum clearance of equipment to structure above.~~
- ~~C. Suspend isolators from substantial structural members, not from slab unless specifically permitted. Attachments to fireproofed structural members shall be re-fireproofed as required.~~
- ~~D. Align hanger rods to clear the hanger box. Replace bent rods.~~
- ~~E. Support pipe for the first three pipe hangers from any rotating equipment with isolator Type C1 with a minimum 1½ inch static deflection~~
- ~~F. Support pipe larger than 2 inches by isolator Type C with a minimum 1½ inch static deflection. Support horizontal pipe 2 inches and smaller by means of Type E isolator with a minimum of 0.25 inch deflation.~~
- ~~G. Domestic water and HVAC piping, one inch diameter and less, shall be isolated using Acousto-Plumb or equal resilient attachments or shall be provided with thermal insulation with shields at support points.~~
- ~~H. Sanitary drain or storm drain piping passing above rooms or spaces requiring NC-35 or less shall be attached and supported using Type C spring hangers for horizontal piping and in vertical piping Type "D" underneath the supporting clamps. Provide Type "F" resilient pads under pipe elbows supported from the floor.~~
- ~~I. All other grouped pipes shall be isolated by using Type "C" vibration isolators supporting trapeze hangers and selected to provide a static deflection of 1.0 inches. Grouped floor-supported pipes shall be isolated using Type "D" isolators selected to provide a static deflection of 0.15 inches.~~
- ~~J. Mount floor supported horizontal pipe at slab using Type A isolator with a minimum static deflection of 1 inch or same deflection as isolated equipment to which pipe connects, whichever is greater.~~
- ~~K. Mount all isolators between building structure and supplementary steel.~~
- ~~L. Suspend isolators from rigid and massive support points.~~
- ~~M. Supplementary steel to be sized for a maximum deflection of 0.08 inches at center of span.~~
- ~~N. Support water piping not subject to thermal expansion with riser floor supports with Type F isolators (2 layers) or Type G pad depending on piping loads and support point space conditions within shafts.~~
- ~~O. Vibration isolation components shall not be used to correct misaligned sections of pipe.~~
- ~~P. Vertical piping subject to thermal expansion shall have pipe riser guides, anchors and supports located so that there will be no direct metal contact of the piping with the building structure.~~
- ~~1. Weld steel guide bars to the pipe at a maximum spacing of 60 feet. The outside diameter of the opposing guide bars shall be smaller than the inside diameter of the pipe riser clamp in accordance with standard field construction practice. Each end of the pipe riser clamp shall be rigidly attached to an all-directional pipe anchor isolation mounting, which in turn shall be rigidly fastened to the supplementary steel framing within the shaft.~~
 - ~~2. The all-directional pipe anchor shall consist of a telescoping arrangement of 2 sizes of steel tubing separated by a minimum of ½ inch thick heavy duty neoprene and canvas duck isolation pad. Provide vertical restraints by similar material arranged to prevent~~

~~vertical travel in either direction. The allowable load on the isolation material shall not exceed 500 pounds per square inch. Anchors shall be Mason Industries Type ADA or equal.~~

~~3. Construct piping guides for insulated piping with a 10-gauge metal sleeve around the piping. Provide the thermal insulation requirements for the piping between the piping and the sleeve. The metal sleeve outside diameter shall be smaller than the pipe riser clamp inside diameter. The pipe riser clamp shall be rigidly attached to the pipe guide, which shall be rigidly attached to the steel framing within the shaft. Guides shall be Mason Industries Type VSG or equal.~~

~~4. The pipe anchor mountings shall be capable of safely supporting loads, expansion, and thrusts developed by the installed piping.~~

~~Q. Provide flexible piping connections for connections to rotating equipment as specified and where shown on the Drawings.~~

~~R. Provide flexible piping connections and four elbow offsets for all piping that crosses building seismic or expansion joints unless more stringent flexible all-directional joints have been specified elsewhere.~~

3.03 SEISMIC RESTRAINTS

A. General:

1. Cable restraints shall be installed slightly slack to avoid short circuiting the isolated suspended equipment, piping or ductwork. Cable restraints shall be installed taut on non-isolated systems. Seismic solid brace restraints may be used in lieu of cables on non-isolated rigidly attached systems only.
2. Where cable or solid brace restraints are located, the equipment, ductwork or piping support rods shall be angle braced for compression loads.
3. At all locations where cable or solid brace restraints are attached to pipe clevises, the clevis cross bolt shall be reinforced with cross braces.
4. Provide drill-in concrete anchors for ceiling and wall installation and female wedge type for floor mounted equipment.

B. Seismic Restraint of Piping:

1. Seismically restrain all piping listed below.
 - a. Fuel oil piping, gas piping, medical gas piping, and compressed air piping that is 1 inch I.D. or larger.
 - b. Piping located in boiler rooms, mechanical equipment rooms, and refrigeration equipment rooms that is 1 1/4 inch I.D. and larger.
 - c. All other piping 2 1/2 inch diameter and larger.
2. Fire protection piping shall be braced in accordance with NFPA 13 and 14.
3. Transverse piping restraints shall be at 40 foot maximum spacing for all pipe sizes, except where lesser spacing is required to limit anchorage loads.
4. Longitudinal restraints shall be at 80 foot maximum spacing for all pipe sizes, except where lesser spacing is required to limit anchorage loads.
5. Where thermal expansion is a consideration, guides and anchors may be used as transverse and longitudinal restraints provided they have a capacity equal to or greater than the restraint loads in addition to the loads induced by expansion or contraction.
6. For fuel oil and all gas piping transverse restraints must be at 20 foot maximum and longitudinal restraints at 40 foot maximum spacing.
7. Transverse restraint for one pipe section may also act as a longitudinal restraint for a pipe section of the same size connected perpendicular to it if the restraint is installed within 24 inches of the elbow or TEE or combined stresses are within allowable limits at longer distances.

8. Hold down clamps must be used to attach pipe to all trapeze members before applying restraints in a manner similar to clevis supports.
9. Branch lines may not be used to restrain main lines.
10. Cast iron pipe of all types, glass pipe and any other pipes joined with a four band shield and clamp assembly shall be braced as in sections 3.02.C.2 and 3.

C. Seismic Restraint of Ductwork:

1. Seismically restrain all duct work with cable or solid brace restraints as listed below:
 - a. Restrain rectangular ducts with cross sectional area of 6 square feet or larger.
 - b. Restrain round ducts with diameters of 28 inches or larger.
 - c. Restrain flat oval ducts the same as rectangular ducts of the same nominal size.
2. Transverse restraints shall occur at 30 foot intervals or at both ends of the duct run if less than the specified interval. Transverse restraints shall be installed at each duct turn and at each end of a duct run.
3. Longitudinal restraints shall occur at 60 foot intervals with at least one restraint per duct run. Transverse restraints for one duct section may also act as a longitudinal restraint for a duct section connected perpendicular to it if the restraints are installed within 4 feet of the intersection of the ducts and if the restraints are sized for the larger duct. Duct joints shall conform to SMACNA duct construction standards.
4. The ductwork must be reinforced at the restraint locations. Reinforcement shall consist of an additional angle on top of the ductwork that is attached to the support hanger rods. Ductwork is to be attached to both upper angle and lower trapeze.
5. A group of ducts may be combined in a larger frame so that the combined weights and dimensions of the ducts are less than or equal to the maximum weight and dimensions of the duct for which bracing details are selected.
6. Walls, including gypsum board non bearing partitions, which have ducts running through them, may replace a typical transverse brace. Provide channel framing around ducts and solid blocking between the duct and frame.

D. Seismic Restraint of Equipment:

1. All mechanical equipment shall be vibration isolated and seismically restrained as scheduled using either inherently restrained vibration isolators or separate all-directional seismic snubbers as specified. Suspended equipment shall be restrained by cable restraints.
2. All fire protection equipment is considered life safety equipment and shall be seismically restrained using the seismic force levels for life safety equipment in table 1.06-1. if higher levels are shown.

E. Seismic Restraint Exclusions:

1. Piping:
 - a. Gas piping less than 1 inch inside diameter.
 - b. Piping in boiler and mechanical rooms less than 1 ¼ inch inside diameter.
 - c. All other piping less than 2 ½ inch inside diameter.
 - d. All piping suspended by individual hangers 12 inch or less as measured from the top of the pipe to the bottom of the support where the hanger is attached. However, if the 12 inch limit is exceeded by any hanger in the run, seismic bracing is required for the run.
 - e. The 12 inch exemption applies for trapeze supported systems if the top of each item supported by the trapeze qualifies
2. Ductwork:

- a. Rectangular and square ducts that are less than 6 square feet in cross sectional area.
 - b. Oval ducts that are less than 6 square feet in cross sectional area based on nominal size.
 - c. Round duct less than 28 inches in diameter.
 - d. All duct suspended by hangers 12 inches or less in length as measured from the top of the duct to the point of attachment to the structure. Hangers must be attached within 2 inches of the top of the duct with a minimum of two #10 sheet metal screws. If the 12 inch limit is exceeded by any hanger in the run, seismic bracing is required for the run.
3. Suspended Equipment:
- a. VAV boxes and fan powered equipment weighing less than 50 pounds and rigidly connected to the supply side of the duct system and supported with a minimum of 4 hanger rods.

3.063.04 INSPECTION

- A. On completion of installation of all vibration isolation devices specified herein, the local representative of the isolation manufacturer, the manufacturer's engineer shall inspect the completed system and submit a report to the Architect indicating the adequacy of the installation and listing any corrective action required.
- B. Replace any component found to be visibly deflected with more substantial components.
- C. Unless otherwise scheduled on the Drawings provide the following Equipment Vibration Isolation and Seismic Restraints:

| Equipment | Deflection (Inches) | Isolator Type | Restraint Type |
|---|---------------------|---------------|----------------|
| Chillers | 2.0 | "B" | |
| Cooling towers | 2.0 | "B" | |
| | 1/6 | "F" | I |
| Roof-mounted exhaust fans | 1.0 | "B" | |
| Packaged air-handling units: | internal isolation | "A" | I |
| | external isolation | "D" | - |
| Suspended fans, heat pumps and air conditioning units, utility sets | 2.0 | "C1" | II |
| Fan coil units and fan powered terminal units | 1.0 | "E" | II |
| Base-mounted pumps – inertia base required | 2.0 | "A" | I |
| Other small pumps and motor driven equipment | 0.35 | "C1" | II |
| Reciprocating air compressors – inertia base required | 3.0 | "A" | I |
| Wall mounted fans and exhaust fans less than ¼ hp | 0.15 | "G" | |
| Wall or floor mounted steam pressure reducing stations and VFD's | 0.15 | "G" | - |

END OF SECTION

SECTION 23 05 50

ACCESS DOORS IN GENERAL CONSTRUCTION

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this section shall include, but is not limited to, the following:

1. Furnishing access doors for installation in general construction.

1.02 SUBMITTALS

A. Shop Drawings: Submit access door locations superimposed on piping layout and duct layout shop drawings. Submit manufacturer's data on access doors including size and type.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Access Doors: Milcor Inc., Karp Associates, Inc., J.L. Industries, Acudor, Williams Brothers

2.02 ACCESS DOOR CONSTRUCTION

A. Provide recessed type as required to accept matching ceiling tile or drywall, etc.

B. Provide UL rated doors for fire rated construction.

C. Provide flush type steel framed panel with concealed continuous piano hinges for masonry or concrete construction. Provide textured frame for drywall construction.

D. Provide cam type locking device. Provide cylinder lock type access doors located in public corridors and washrooms complete with master keys.

E. Provide insulated doors in insulated or acoustically rated construction.

2.03 Furnish access doors of proper size for access to concealed equipment. Unless otherwise indicated, minimum size to be 12-inch x 12-inch for hand access and minimum 18-inch x 18-inch for valve and actuator access and 24-inch x 24-inch for equipment access. The following schedule is based on Karp Associates Inc.:

A. Rated Construction: Fire rated access door UL "B" Label Model KRP

B. Non-Rated Dry Wall Construction: Model KDW

C. Non-Rated Masonry, Concrete: Model DSC 214-M

D. Non-Rated Ceramic Tile, Stainless Steel, Satin Finish: Model DSC 214-M

E. Non-Rated Plaster Wall: Model DSC 214-PL

F. Non-Rated Plaster Ceilings: Model DSC 210-PL

2.04 Provide color-coded dots on access doors to indicate type of service.

PART 3 – EXECUTION

3.01 Coordinate location of access doors in hung ceilings, furred spaces, walls, etc., to provide access to concealed work items requiring maintenance and/or adjustment. Obtain approval of the Architect for the locations of such access doors.

3.02 Locate and group equipment requiring access doors. Coordinate location of equipment with other trades to minimize number of access doors in one area.

3.03 Provide access doors for maintenance or adjustment purposes for mechanical system components, including but not limited to the following:

- A. Valves
- B. Dampers
- C. Concealed equipment

3.04 Access doors shall be marked by small color markings at corner of tile or door in accordance with the following color assignments:

- HVAC - Blue
- Fire Protection - Red
- Plumbing - Silver

END OF SECTION

SECTION 23 05 53

SYSTEMS IDENTIFICATION

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Valve and automatic damper identification
 - 2. Equipment identification
 - 3. Piping and ductwork identification

1.02 SUBMITTALS

- A. Shop Drawings: Submit the following:
 - 1. Valve and damper identification chart
 - 2. Lists of pipe and equipment to be labeled
 - 3. Color chart
- B. Product Data: Manufacturer's latest published data for materials, equipment and installation, including samples of valve and damper tags, equipment identification and piping identification.
- C. Maintenance Manuals: Provide valve and damper tag schedules for inclusion in maintenance manuals.

1.03 REFERENCE STANDARDS

- A. American National Standards Institute (ANSI): A13.1 – 1981: Scheme for Identification of Piping Systems.

1.04 QUALITY ASSURANCE

- A. Piping identification shall comply with ANSI Standard A13.1.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Brady/Seton
- B. Stranco

2.02 VALVE AND DAMPER IDENTIFICATION

- A. All tagged components shall be in accordance with ANSI A13.1-1981.
- B. For valves and automatic dampers, use metal tags 2-inch minimum diameter, fabricated of brass, stainless steel or aluminum.
 - 1. Attach tags with jack chain s-hook or split ring of same materials.
 - 2. For stamped tags, use ¼-inch high letters.

2.03 LABELS

- A. Labels shall have 2-inch high letters and integral directional flow arrows. Smaller letters may be used only when space does not permit 2-inch high lettering.
 - 1. For piping up to 5-inch diameter, use pre-formed snap-on markers Seton "Setmark" or equal. For piping 6-inch diameter and up, use pre-formed strap-on markers Seton "Setmark" or equal.
 - 2. Pressure sensitive tapes are unacceptable.

2.04 EQUIPMENT IDENTIFICATION

- A. Mechanical equipment shall be identified by means of nameplates permanently screw fastened to the equipment. Nameplates shall be black surface, white core laminated bakelite with engraved letters. Plates shall be a minimum of 3-inch long by 1-inch wide with white letters 3/8-inch high.
- B. Identification of Automatic Controls: Refer to Section 23 09 00 - Building Management System.
- C. Terminal equipment installed in ceiling spaces such as variable volume terminals, fan coil units, heat pumps, etc., shall have identifying number stenciled on bottom of unit so that it is visible from below.

PART 3 – EXECUTION

3.01 VALVE AND AUTOMATIC DAMPER IDENTIFICATION

- A. Do not identify valves where the use is obvious, such as equipment isolation valves.
- B. Provide schedules of all valves showing number, size, type and service of each valve. Provide separate list for each separate hydronic system. Incorporate in maintenance manuals.
- C. Tag automatic dampers with identical letters or numbers as shown on Drawings.

3.02 EQUIPMENT IDENTIFICATION

- A. Identify equipment with identical letter and/or number as used on Drawings. Where space is available use full name of equipment. Attach nameplates in a permanent manner in a location that will be clearly visible after installation is complete.
- B. Controls identification shall be specified in Section 23 09 00 - Building Management Systems. Also identify controls not included in Section 23 09 00 such as float switches, alarms, remote pushbutton switches with 1/4-inch high lettering and laminated plastic plates screwed or chained to equipment.

3.03 PIPING IDENTIFICATION

- A. Piping identification shall be in conformance with the ANSI A13.1-1981.
- B. Identify piping systems with color-coded bands, sharply contrasting with background. Locate bands near strategic points, such as valves, items of equipment, changes in direction, wall penetrations, capped stub out for future connection and every 40 feet of straight runs. If necessary, paint a strip background of black or white to obtain contrast.
- C. Apply bands where they can be easily read. Provide bands with backgrounds of different

colors.

- D. Drain piping serving mechanical equipment items for which the drain discharge is not visible from the equipment shall be marked near the point of discharge indicating the item of equipment served.

3.04 ACCESS IDENTIFICATION

- A. Identify service, damper, duct access door, piping and equipment behind all architectural access doors.
- B. Removable ceiling tile shall be marked by small color markings at corner of tile or door in accordance with the following color assignments:

| | | |
|-----------------|---|--------|
| HVAC | - | Blue |
| Fire Protection | - | Red |
| Plumbing | - | Silver |

END OF SECTION

MECHANICAL SYSTEMS BALANCING

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
1. Adjust and balance hydronic systems.
 2. Adjust and balance domestic hot water systems.
 3. Adjust and balance air systems.
 4. Perform acoustic measurements to systems.
 5. Perform airflow measurements for smoke control system zones and stair and vestibule pressurization tests.

1.02 QUALITY ASSURANCE

- A. Each balancing contractor providing a bid for this work shall submit the following information with the bid, or the bid shall not be accepted by the Owner.
1. List previous projects of similar scope with dates that projects were executed.
 2. Outline organization of contractor, including names of principals, years of operation, address, and phone number.
 3. List instruments owned by Contractor and procedures that will be used on this project.
 4. List name of job site supervisor that will execute this work and a resume of individual's specific work experience.
 5. Provide a sample of a balance report on a project of similar scope.
- B. The final balancing, testing, and adjustments of the complete mechanical systems shall be the direct responsibility of the balancing contractor, including all costs for doing this work and provision of the personnel, materials, tools, and instrumentation to accomplish this work. Meet standards contained in the AABC National Standard Chapter 17 through 26 and other criteria as set forth in these specifications.
- C. The Contractor must primarily be engaged in the balancing and testing of heating, ventilating and air conditioning systems. The Contractor must be AABC certified.

1.03 PROCEDURES

- A. General: Prior to commencement of balancing, review proposed schedule, methods and instruments to be used in balancing with the Architect. Include descriptive data, procedure data and sample forms.
- B. Descriptive Data: Review contract documents, shop drawings released for construction, design concepts and general function of each system including associated equipment and operation cycles. Confirm listing of flow and terminal measurements to be performed; selection points for proposed sound measurements.
- C. Procedure Data: Outline procedures for taking test measurements to establish compliance with requirements. Specify type of instruments to be used, method of instrument application (by sketch) and correction factors. Verify access to valves, dampers and equipment for test and balancing.
- D. Sample Forms: Submit forms showing application of procedures to typical systems. Forms shall be of AABC format.

- E. AABC test sheets required are as follows:
1. Air Moving Equipment Test Sheet
 2. Exhaust Fan Test Sheet (Supply, Return, Relief Fans)
 3. Air Inlet and Outlet Test Sheet
 4. Water Balance Element Test Sheet
 5. Circulating Water Pump Data Sheet
 6. Duct Traverse Zone Totals Sheet
 7. Duct Traverse Readings Sheet

1.04 SUBMITTALS

- A. Submit excerpts from recent previous final balancing reports.
- B. Submit certification of most recent calibration of all instruments to be used on this project.

1.05 CONTRACTOR COOPERATION

- A. The balancing contractor shall check and report defects or deficiencies that may affect balancing.
1. Mechanical contractor shall cooperate with the balancing contractor to:
 - a. Provide sufficient time before final completion date and individual equipment manufacturer's start-up so that balancing can be accomplished.
 - b. Provide immediate materials, labor and tools to make corrections without delay.
 - c. Place heating, ventilating and air conditioning systems and equipment into full operation and continue the operation for each working day of testing and balancing.
 - d. Advise testing and balancing contractor of changes made to the system during construction.
 - e. Install required test holes or wells complete with removable and replaceable plugs or caps.
 - f. Make necessary revisions to controls, valves, dampers, fan and pump drives and consult with equipment manufacturers as required to achieve the specified system's performance.
 - g. Supply and install dampers as specified and shown on drawings, and where required to obtain final system balance.
 - h. Provide lifts, ladders, scaffolds, tools and labor to assist the work of the balancing contractor, including removing ceiling tiles, guards, adjusting pulleys, belts; replace when finished.
 - i. Building Management System contractor shall cooperate with and work with the balancing contractor when setting damper linkages, minimum outside air dampers, and other air volume devices, and shall be available for readjusting of dampers, devices or controls that are not properly calibrated.
 - j. Set pressure regulating and reducing valves to operating and code conditions.
 - k. Check and set relief and safety valves to code requirements.
 - l. Clean strainers. Check air filters immediately prior to air balancing.
 - m. Open fire dampers. Provide certification of damper operation as required by Section 23 33 13 - Dampers.
 - n. Verify return air openings have been provided in full height walls as specified, shown on the Drawings or as required for proper balancing and system operation.
 - o. Variable pitch sheaves supplied on 20 horsepower motors and larger shall be changed to fixed sheaves after the air balance is completed. Provide such sheaves.

PART 2 – PRODUCTS

2.01 INSTRUMENTS

- A. Instruments for testing and balancing of air and hydronic systems shall have been calibrated within a period of 6 months and verified for accuracy prior to start of work.
- B. Submit a list of equipment, which will be used for the balancing of systems and test and calibration certification by an independent instrument calibration laboratory indicating date of test, and test results showing accuracy and repeatability are within limitations acceptable to the AABC.

PART 3 – EXECUTION

3.01 GENERAL PROCEDURE

- A. Balance to maximum measured flow deviation from specified values of 10 percent at terminal device and 5 percent at equipment or mean sound level deviation of 15 decibels.
- B. Permanently mark settings on valves, splitters, dampers and other adjustment devices.
- C. Take measurements to verify balance has not been disrupted or that such disruption has been rectified.
- D. At final inspection, recheck random selections of data recorded in report. Recheck points or areas as selected and witnessed by the Architect.
- E. At the completion of balancing procedures, allow for a minimum of 2 days for the Architect to witness test procedures and conduct operational tests.

3.02 SITE VISITS

- A. A review of the installation shall be made prior to commencing balancing work and any additional dampers or valves required for proper balance shall be reviewed with the Architect and the Contractor.
- B. The Test and Balance Contractor shall visit the job site a minimum of 3 times during the ductwork, equipment and piping installations. Site Visit Reports shall be submitted to the Architect listing any deficiencies found. Identify in the report any additional balancing valves or dampers required.

3.03 ACCEPTANCE

- A. Mechanical systems shall not be considered ready for final inspection until balancing results acceptable to the Architect are obtained.
- B. If it is found that the specified airflows cannot be achieved on portions of the system, the actual conditions shall be reported to the Architect for consideration of corrective action before continuing the balance procedure.
- C. If measured flow at final inspection shows deviation of 10 percent or more or mean sound level deviation of 10 decibels or more from the certified report listings for more than 10 percent of selected areas, the report shall be rejected.
- D. If report is rejected, systems shall be rebalanced and a new certified report submitted.

3.04 BALANCING REPORT

- A. Submit a draft copy of reports prior to final acceptance of project. Provide copies of final report for inclusion in Operating and Maintenance Manuals.
- B. Provide reports in durable soft cover, 3-ring binder manuals, complete with table of contents, indexing tabs and cover identification at front and side.
- C. Include types, serial number and dates of calibration of instruments.
- D. Record test data on a sepiamade from the latest available revised set of mechanical shop drawings and submit copies upon completion of the balancing contract.
- E. Install at each piece of mechanical equipment a "Data Register" showing significant operating temperatures, pressures, amperes, voltage, and brake horsepower. "Data Register" shall be enclosed in a hard, clear plastic holder securely attached to the equipment or to a wall in the adjacent area.
- F. Submit with report, fan and pump curves with operating conditions plotted. Submit grille and diffuser shop drawings and diffusion factors.
- G. Report shall be indexed as follows:
 - 1. Air
 - a. Summary
 - b. Procedure
 - c. Instrumentation
 - d. Drawings
 - e. Equipment Summary
 - f. Fan Sheets
 - g. Fan Curves
 - h. Fan Profile Data
 - i. Static Data
 - j. Air Monitoring Station Data
 - k. Traverse Data and Schedule
 - l. Terminal Unit Summary
 - m. Outlet Data Summary and Schematics (per system)
 - n. Building Pressurization Data
 - o. Smoke Exhaust Mode Data
 - p. Stairway and Stair Vestibule Pressurization Data
 - q. Smoke Control System Testing (Smoke Control Zone Supply, Relief and Exhaust Capacities)
 - 2. Water
 - a. Summary
 - b. Procedure
 - c. Instrumentation
 - d. Pump Data
 - e. Pump Curves
 - f. Flow Stations
 - g. Coils
 - h. Equipment Data
 - i. Element Data Summary and Schematics (per system)
 - 3. Sound
 - a. Summary

- b. Procedure
 - c. Instrumentation
 - d. Drawings
 - e. Profile
 - f. Scale Readings
- 4. Fire Damper Certification
 - 5. Copy of Contractor's Certification

3.05 AIR SYSTEM PROCEDURE

- A. Execute air systems balancing for each air system in accordance with AABC specifications and as described herein.
- B. Make tests with supply, return and exhaust systems operating and doors, windows, closed or in their normal operation condition.
- C. Test and adjust fan or blower speed to design requirements.
- D. Test and record motor full load amps. Record each installed motor manufacturer and motor efficiency.
- E. Traverse main supply air ducts, using a pitot tube and manometer. Calibrate the manometer to read two significant figures in velocity pressure ranges. Take a minimum 16 readings per traverse. The intent of this operation is to measure by traverse the total air quantity supplied by the fan and to verify the distribution of air to zones. A main duct is defined as any of the following:
 - 1. A duct serving 5 or more outlets.
 - 2. A duct serving 3 or more branch ducts.
 - 3. A duct serving a hydronic coil.
 - 4. A zone duct from a fan powered VAV terminal unit.
 - 5. A duct emanating from a fan discharge or plenum and terminating at one or more outlets.
- F. Submit data in support of supply fans deliveries by the following four methods. For return, relief and exhaust fans, methods 1 and 4 are sufficient:
 - 1. By summation of the air quantity readings at inlets or outlets.
 - 2. By duct traverses of main supply ducts.
 - 3. By rotating vane traverse across the filter bank or coil bank.
 - 4. By plotting revolutions per minute and static pressure readings on the fan curve. Air density corrections must be indicated.
- G. Test and record required and measured system static pressures; filter differential, coil differential and fan total static pressure.
- H. Test and adjust systems for design recirculated airflow rates.
- I. Test and adjust system for design outside airflow rates.
- J. Test and record entering and leaving air temperatures.
- K. Install one-inch roll media filters upstream of air filters to impose 90 percent of the manufacturer's recommended final filter air pressure drop.
- L. Adjust main supply and return ducts to proper design flow rates.

- M. Inspect and confirm all fire dampers are open, all smoke dampers and fire/smoke dampers are in their correct position, all duct access doors are closed and fire damper fusible links are accessible.
- N. Adjust zones to proper design, supply and return flow rates.
- O. Test and adjust each air inlet and air outlet and transfer duct to within 10 percent of design requirements.
- P. Identify each air inlet, air outlet, transfer duct and transfer wall opening as to location and area.
- Q. Identify and list size, type and manufacturer of diffusers, grilles, registers and testing equipment. Use manufacturer's rating on equipment to make required calculations.
- R. In readings and tests of diffusers, grilles and registers, report the required face and neck velocity, test face and neck velocity, and required air pressure drop and flow rate. Test after adjustments.
- S. Building Management System contractor shall set adjustments of automatically operated inlet vanes, cones, plugs and all dampers to operate as indicated in cooperation with balancing contractor.
- T. Adjust diffusers, grilles and registers to minimize drafts, dumping, and to prevent "short circuiting" between supply and return outlets.
- U. Use volume control devices to regulate air quantities only to extent that adjustments do not create objectionable air motion or sound levels. Effect volume control by duct internal devices such as dampers and splitters. Remove air slots on return air troffers to achieve adequate relief and minimize pressure drop into the ceiling plenum.
- V. Vary total system airflow rates by adjustment of fan speeds or fan volume-varying devices. Vary branch air quantities by damper regulation.
- W. Record installed fan drive assemblies; fan sheaves, motor sheaves, belts and motors.
- X. For fans with two-speed motors, execute the entire air systems procedure at both speeds. This also applies to fans with variable frequency drives when used in normal mode and smoke control modes.
- Y. The final balanced condition of each area shall include testing and adjusting of pressure conditions. Test and record building pressurization levels in variable volume systems throughout full range of fan delivery rates, under both heating and cooling conditions. For multi-story buildings, test pressure conditions at ground, intermediate and upper levels. Front doors, stair and vestibule doors, exits and elevator shafts shall be checked for airflow so that leakage does not cause excessive or abnormal pressure conditions. Document abnormal building leakage conditions noted.
- Z. Complete balancing to achieve positive building pressure unless otherwise instructed. A positive pressure relative to outside of 0.05-inch water gauge minimum and 0.10-inch water gauge maximum shall be achieved, measure with negligible, outside wind velocity.
- AA. Complete balancing of the refrigeration machinery room intake and exhaust air systems to maintain a negative pressure of 0.05-inch water gauge minimum relative to adjacent spaces.
- BB. Test stairway and stair vestibule pressurization fans. Measure air quantity delivered by fan and inlet points. Measure airflow rate through relief openings in stairway. Measure pressure differential between floor area, vestibule and stairwell in three locations per stair (2nd floor,

mid-height, top floor).

3.06 FIRE AND LIFE SAFETY VENTILATION SYSTEMS PROCEDURE

- A. All testing and balancing is required for equipment, systems and terminal devices during normal operation and fire alarm and life safety operation.
- B. The life safety and smoke control and ventilation systems shall be performance tested by demonstration of the proper sequences of the fire and life safety ventilation system, automatic damper operation, stair and vestibule door opening and closing forces and other functions involved. Tests shall demonstrate the activation of the smoke detection system and smoke control system, in accordance with the procedures and test criteria established by the local authorities having jurisdiction. The mechanical, fire protection, fire alarm, electrical, and Building Management System contractor and the General Contractor shall be present and shall participate during the entire testing procedures. The mechanical subcontractor shall furnish the smoke bombs, ladders, tools, etc.
- C. The Contractor shall verify and record that the required pressure differences, the required quantity of air specified or indicated on the Drawings is supplied, relieved or exhausted. Tests shall demonstrate the proper sequence of the fire safety ventilation systems, the activation of the smoke detection system, smoke control system, and make-up air systems. The smoke control systems installed in this Project shall be performance tested in accordance with the requirements of the authorities having jurisdiction and the fire department. The demonstration tests shall be conducted and repeated until they are accepted and approved by the authorities having jurisdiction. The mechanical subcontractor shall include all costs associated with the required demonstration tests, including smoke bombs, instrumentation, etc. Perform a minimum of one successful test of each sequence witnessed by the Architect prior to any demonstration test for authorities having jurisdiction.

3.07 HYDRONIC SYSTEMS PROCEDURE

- A. Preparation of System – Phase I: The hydronic system shall be prepared for balancing in the following manner:
 - 1. Open valves to full position including coil stop valves; close bypass valves; and return line balance valves.
 - 2. Examine water in system to determine if it has been treated and is clean.
 - 3. Check pump rotation.
 - 4. Check expansion tanks to ensure that they are not air bound and that the system is full of water.
 - 5. Check air separators and air vents at hydronic coils and high points of water systems to ensure that they are installed properly and are operating freely. Make certain all air is removed from circulating system.
 - 6. Set temperature controls to close all automatic bypass valves and provide full flow through hydronic coils or heat exchangers.
 - 7. Check operation of automatic bypass valves.
 - 8. Check and set operating temperature of heat exchanger, cooling tower, boiler and chiller at design requirements.
 - 9. Execute air balance before water balance is initiated.
- B. Test and Balance Procedure – Phase II:
 - 1. Check operation of variable speed pump and record pump data at varying percentages of full flow.
 - 2. Set pumps to deliver approximately 10 percent excess flow volume if possible. Do not overload motors.
 - 3. Adjust flow through chiller, heat exchanger, cooling towers and boilers.
 - 4. Check and record entering and leaving water temperatures and pressure drop through chillers, boilers, cooling towers and heat exchangers. Reset to design

- temperatures.
- 5. Check and record water temperature at inlet side of coils. Note rise or drop of temperatures from source.
- 6. Where automatic flow control valves are installed verify that the operating pressure differential across the valve taps is within the range indicated on the submittal data sheet for that model number.
- 7. Position and mark/lock manual calibrated balance valves for design flow through coils, AC units, heat pumps, convectors and all other items in system requiring circulation of glycol, chilled water, hot water or condenser water.
- 8. For venturi type, pitot tube, or other flow measuring devices, record the pipe size, manufacturer and size of device, and the direct reading of the differential pressure, and calculated final flow.
- 9. Upon completion of flow readings and coil adjustments, mark settings and record data.
- 10. Ensure bypass valves are tightly closed.

C. Test and Balance Procedure – Phase III:

- 1. After making adjustments to coils, recheck settings at pumps. Readjust if required.
- 2. Install pressure gauges on each coil then read pressure drop through coil and set flow rate on call for full flow through coil. Set pressure drop across bypass valve to match coil full flow pressure drop.
- 3. Balance flow through equipment and coils by means of pressure drop. Obtain curves from the various manufacturers indicating the relationship between flow and pressure drop through the coils and equipment. Take readings on calibrated test gauges.
- 4. Upon completion of the water balance, reconcile the total heat transfer through coils by recording the entering and leaving water temperatures and the entering and leaving air dry bulb and wet bulb temperatures.
- 5. Upon completion of balancing, adjust differential bypasses for the same pressure drop on full bypass as on full flow.

3.08 DOMESTIC HOT WATER SYSTEMS PROCEDURE

A. Preparation of System – Phase I: The domestic hot water return system shall be prepared for balancing in the following manner:

- 1. Close bypass valves.
- 2. Open valves to full position including; and return line balance valves.
- 3. Examine water in system to determine if it has been flushed and chlorinated.
- 4. Check circulation pump rotation.
- 5. Check thermal expansion tanks to ensure that they are not air bound and that the system is full of water and air charged to correct pressure.
- 6. Open faucets at upper floor to release air from systems then close when air is removed from circulating system.
- 7. Verify normally open port of thermal mixing valve is the port, which return water and cold water is connected to. Verify hot water return line also returns to the cold water side of water heaters. Check direction of flow of check valves.
- 8. Check and set operating temperature of water heater at design requirements.

B. Test and Balance Procedure – Phase II:

- 1. Check operation of circulation pump and record pump data at full flow.
- 2. Adjust flow through each circulation loop by proportional balancing techniques.
- 3. Check and record entering and leaving water temperatures and pressure drop through water heaters. Reset to design temperatures.
- 4. Check and record water temperature at inlet side of water heater.
- 5. Position and mark/lock balance valves for design flow through hot water return lines.
- 6. For venturi type, pitot tube, or other flow measuring devices, record the pipe size,

manufacturer and size of device, and the direct reading of the differential pressure, and calculated final flow.

7. Upon completion of flow readings, mark settings and record data.
8. Ensure bypass valves are tightly closed.
9. Adjust temperature of thermostatic mixing valve to operating temperatures.

C. Test and Balance Procedure – Phase III:

1. After making adjustments to mixing valves and balance valves recheck settings at pumps. Read just if required.
2. Balance flow through return loops by pressure drop to obtain specified flows per loop. Obtain curves from the various manufacturers indicating the relationship between flow and pressure drop through balance valves. Take readings on calibrated test gauges.

D. Upon completion of balancing, check water temperature at most remote hot water branch and record time of delivery of hot water at constant temperature and record the temperature.

3.09 BALANCING DATA

A. Air Handling Equipment Installation Data:

1. Manufacturer, model and size
2. Arrangement, discharge and class
3. Motor type, horsepower, speed, efficiency, voltage, phase, cycles and full load amperes
4. Location and final identification

B. Air Handling Equipment Design Data:

1. Total airflow rate
2. Static pressure across coil, filter, damper, mixing box sections and total
3. Motor horsepower, speed, efficiency, voltage and amperes
4. Fan speed and brake horsepower
5. Hydronic coil inlet and outlet, dry bulb temperatures
6. Initial filter air pressure drop

C. Air Handling Equipment Recorded Data:

1. Total airflow rate
2. Static pressure across coil, filter, damper, mixing box sections and total
3. Fan speed and brake horsepower
4. Motor operating amperes
5. Inlet and outlet, dry bulb temperatures
6. Filter air pressure drop

D. Duct Air Quantities: Mains, Branches, Outside Air and Exhausts (Maximum and Minimum):

1. Duct sizes
2. Number of pressure readings
3. Sum of velocity measurements
4. Average velocity
5. Duct recorded airflow rate
6. Duct design airflow rates

E. Air Inlets and Outlets:

1. Inlet/outlet identification location and designation
2. Manufacturer's catalogue identification and type

3. Application factors
4. Design and recorded velocities
5. Design and recorded airflow rates
6. Deflector vane or diffuser cone settings

F. Building Pressurization Data:

1. Outside air temperatures and humidities
2. Outside wind velocity
3. Building pressures plotted with respect to systems
4. Supply air, return air and exhaust airflow rates for varying damper positions
5. Locations of pressure measuring points, inside and outside building

~~G. Stair and Stair Vestibule Pressurization Data:~~

- ~~1. Stair Supply airflow rates~~
- ~~2. Exhaust or relief opening flow rates~~
- ~~3. Vestibule to floor pressure differential each floor~~
- ~~4. Stair to vestibule pressure differential each floor~~

~~H. Smoke Exhaust Data: Supply and Exhaust Flow Rate~~

G. Pump Installation Data:

1. Manufacturer, model and size
2. Impeller diameter
3. Drive type
4. Motor type, horsepower, efficiency, speed, voltage, phase, cycles and full load motor amperes

H. Pump Design Data:

1. Flow rate and head pressure
2. Pump speed and horsepower
3. Pump efficiency

I. Pump Recorded Data:

1. Discharge and suction pressures (full flow and no flow)
2. Operating pressure and total dynamic head
3. Operating rate (from pump curves if metering not provided or from variable speed controller)
4. Motor operating amperes
5. Balancing valve setting (full open, 60 percent open etc.)

J. Expansion Tank Installation Data:

1. Manufacturer, size, capacity
2. Pressure reducing valve setting
3. Pressure relief valve setting

K. Heating Equipment Design Data:

1. Heat transfer rate
2. Flow rates and pressure drops
3. Entering and leaving water temperature

L. Heating Equipment Recorded Data:

1. Element type and identification (location and designation)
 2. Entering and leaving temperatures
 3. Flow rates and pressure drops
- M. Heat Exchanger Installation Data:
1. Manufacturer, model, type
 2. Water flow rates
 3. Inlet and outlet temperatures both fluid streams
- N. Heat Exchanger Recorded Data:
1. Heat transfer fluid media flow rates
 2. System entering and leaving temperatures and pressures
 3. Entering and leaving heating water temperatures and pressures
- O. Air Heating and Cooling Equipment Design Data:
1. Heat transfer rate
 2. Water pressure drop across coil
 3. Air static pressure drop
 4. Entering and leaving water temperatures
 5. Entering and leaving air dry and wet bulb temperatures
- P. Air Heating and Cooling Equipment Recorded Data:
1. Element type and identification
 2. Entering and leaving air dry and wet bulb temperatures
 3. Entering and leaving water temperatures
 4. Water pressure drop across coil
 5. Water pressure drop across bypass valve
 6. Air static pressure drop
 7. Air and water flow rates
 8. Adjusted temperature rise or drop
- Q. Water Chiller Installation Data:
1. Manufacturer and model
 2. Motor type, kilowatts, speed, voltage, cycles, phase and full load amperes
 3. Water flow rates
 4. Water pressure drops
 5. Entering and leaving water temperatures
- R. Water Chiller Recorded Data:
1. Water flow rates
 2. Water pressure drops
 3. Entering and leaving water temperatures
 4. Running load kilowatts
- S. Humidifier Installation Data:
1. Manufacturer, model and size
 2. Maximum kilowatts, voltage, phase, cycles
- T. Humidifier Recorded Data:
1. Running load amperes

2. Entering and leaving air humidity
3. Length of vapor trail in air stream

~~W. Ice Storage Plant Installation Data:~~

- ~~1. Manufacturer and model~~
- ~~2. Flow rate (charge/discharge)~~
- ~~3. Inlet temperature (charge/discharge)~~
- ~~4. Outlet temperature (charge/discharge)~~

~~X. Ice Storage Plant Recorded Data over a Complete Freeze/Melt/Charge Cycle:~~

- ~~1. Flow rate (charge/discharge)~~
- ~~2. Inlet temperature (charge/discharge)~~
- ~~3. Outlet temperature (charge/discharge)~~

U. Sound Level Data:

1. Diagram or description of relationship of sound source to measuring instrument
2. Overall decibels (A) level
3. Reading at each octave band frequency from 31.5 Hz to 16 kilohertz
4. Noise criteria (NC) curves plotted and compared to those recommended by ASHRAE or AABC publications

V. Sound Level Recorded Data:

1. Air Inlets and Outlets
2. VAV Terminal Units
3. Air Handling Units
4. Chillers
5. Cooling Towers
6. Boilers
7. VFDs
8. Fans
9. AC Units

END OF SECTION

SECTION 23 07 00

INSULATION

PART 1 – GENERAL

1.01 WORK INCLUDED

- A. The work of this section shall include, but is not limited to, the following:
 - 1. Duct insulation, jackets
 - 2. Piping insulation, jackets
 - 3. Equipment insulation and covering
 - 4. Breeching insulation

1.02 SUBMITTALS

- A. Product Data: Provide product description, list of materials and thickness for each service or equipment scheduled, locations, and manufacturer's installation instructions.
- B. Submit details of sheet metal boxes for pieces of insulated equipment. Refer to 2.06.A.7.

1.03 ENVIRONMENTAL REQUIREMENTS

- A. Maintain ambient temperatures and conditions during storage and installation of all products required by manufacturers of adhesives, mastics, and insulation cements.
- B. Protect insulation from contact with water.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

- A. Insulation with/without Integral Jackets: Owens-Corning Fiberglass; Johns Manville; Armstrong; Certain-Teed, PPG.
- B. Adhesives and Sealers: Ductmate, Benjamin Foster (BF); Insul-Cooustic (IC); 3M, Childers.
- C. Jackets: Childers; Johns Manville.
- D. Premolded fitting, valve, strainer and equipment insulation: Extol of Ohio Inc,

2.02 GENERAL

- A. Conform to application schedule for type and thickness of insulation.
- B. Insulation, jacket, facing and adhesives shall be noncombustible material meeting Code requirements and fire and smoke hazard ratings as tested by procedure ASTM E-84, National Fire Protection Association 225, and UL 723, not exceeding Flame Spread 25 and Smoke Developed 50.
- C. Adhesive, mastic or Insulating material shall not contain asbestos.
- D. Vapor jacket permeance shall be 0.02 perms or less.
- E. Jacket puncture resistance shall be 50 units (Beach) or greater.

2.03 PIPE INSULATION

A. Materials:

1. Glass Fiber: ASTM C547; rigid molded, noncombustible.
 - a. Installed 'K' Value: 0.23 BTU-inch per hr-square foot-degree F at 75°F.
 - b. Maximum Service Temperature: 850°F.
 - c. Vapor Retarder Jacket: White kraft paper, vinyl coated, embossed and reinforced with glass fiber yarn and bonded to aluminum foil, secure with self sealing longitudinal laps and butt strips.

2. Hydrous Calcium Silicate: ASTM C533; rigid molded pipe.
 - a. Installed 'K' Value: 0.40 BTU-inch per hr-square foot-degree F at 300°F.
 - b. Maximum Service Temperature: 1200°F.
 - c. Tie Wire: 16-gauge stainless steel with twisted ends on maximum 12-inch centers.

3. Elastomeric Foam: ASTM C534 flexible cellular elastomeric, molded or sheet.
 - a. Installed 'K' Value: 0.27 BTU-inch per hr-square foot-degree F at 75°F.
 - b. Maximum Service Temperature: 220°F.

4. Field Applied Jackets.
 - a. PVC Plastic: One piece molded type fitting covers and sheet material, gloss white. Connections shall be pressure sensitive color matching vinyl tape.
 - b. Canvas Jacket: UL listed fabric, 6 ounce per square yard, plain weave cotton treated with dilute fire retardant lagging adhesive.
 - c. Aluminum Jacket: 0.016-inch thick sheet, stippled finish, with longitudinal slip joints and 2-inch laps, die shaped fitting covers with factory attached protective liner.
 - d. Stainless Steel Jacket: Type 304 stainless steel, 0.010 inch, smooth finish.

2.04 PIPE INSULATION SCHEDULES

A. Insulation Schedules:

| Service | Temperature Range (degrees F) | Material | Runouts* | Insulation Thickness (inches) for Pipe Sizes: | | | | |
|--|-------------------------------|------------------|----------|---|---------|---------|--------|----------|
| | | | | 1 and less | 1¼ to 2 | 2½ to 4 | 5 to 6 | 8 and up |
| Steam (125 pounds per square inch and higher) | 351 to 450 | Calcium silicate | — | 3½ | 3½ | 4 | 4½ | 4½ |
| Steam (16 to 124 pounds per square inch), steam condensate, hot water heating | 251 to 350 | Glass fiber | 2 | 2 | 2½ | 2½ | 3½ | 3½ |
| Steam (15 pounds per square inch and lower), hot water heating, domestic hot water | 141 to 250 | Glass fiber | 1 | 1½ | 1½ | 2 | 2 | 2 |
| Steam condensate, hot water heating, domestic hot water, domestic recirculated hot water | 105 to 140 | Glass fiber | ½ | 1 | 1 | 1½ | 1½ | 1½ |

| Service | Temperature Range (degrees F) | Material | Runouts* | Insulation Thickness (inches) for Pipe Sizes: | | | | |
|---|-------------------------------|-------------------------------|----------|---|---------|---------|--------|----------|
| | | | | 1 and less | 1¼ to 2 | 2½ to 4 | 5 to 6 | 8 and up |
| Chilled water, glycol, domestic cold water | 40 to 60 | Glass fiber | ½ | 1 | 1 | 1 | 1 | 1 |
| Chilled water, refrigerant, brine, glycol | Below 40 | Elastomeric foam, glass fiber | 1 | 1 | 1½ | 1½ | 1½ | 1½ |
| Underground piping | All | Preinsulated pipe | -- | Refer to Section 23-21-13: Piping and Accessories | | | | |
| Condensate drains above hung ceilings | All | Glass fiber | -- | ½ | ½ | ½ | - | - |
| Roof drain bodies and vertical drop to horizontal piping | All | Glass fiber | -- | -- | 1½ | 1½ | 1½ | 1½ |
| Horizontal roof drainage piping and first 18 inches of vertical riser | All | Glass fiber | -- | -- | 1½ | 1½ | 1½ | 1½ |
| Plumbing vents within 10 feet of atmosphere | All | Glass fiber | -- | -- | 1 | 1 | 1 | 1 |
| Heat traced piping | All | Glass fiber | -- | 1½ | 1½ | 1½ | 1½ | 1½ |
| Diesel engine exhaust and silencer | All | Calcium silicate | -- | -- | -- | 4½ | 4½ | 4½ |
| Hot water and drain piping below lavatories | All | Glass fiber | -- | 1½ | 1½ | 1½ | -- | -- |
| Humidifier steam distribution to tubes or grid | All | Glass fiber below 40 | -- | 1½ | 1½ | -- | -- | -- |

* Runouts are up to 2 inch piping directly connected to a fan coil, heat pump, AC unit, unit heater, terminal unit or radiation and not exceeding 12 feet in length.

B. Fittings, Valves and Flanges:

1. Use factory premolded fittings of the same materials and thickness as the pipe insulation for fittings, flanges and valves.
2. Where premolded insulation fittings are not manufactured, insulate fittings, flanges, strainers and valves with mitered segments of the same density as the adjoining pipe covering. Vaporseal for cold (below dew point) applications using adhesive with open weave glass mesh lay in while wet. Provide a final coat of adhesive. Overlap glass mesh and outer coat adjacent covering by a minimum of 2 inches. Adhesive shall be IC 501 or BF 30-35.
3. Provide insulation for the removable covers and flanges of pipe strainers on cold services with built-up sections of glass fiber pipe covering, arranged to facilitate servicing of the strainer. Complete applications with vaporseals as specified above. Vapor barriers shall be sealed and continuous through guides, hangers, walls, sleeves, etc. Adhesives and coatings shall be as noted herein.
4. Insulate fittings, flanges, valves, etc. for services where calcium silicate insulation is specified with mineral wool cement of equal thickness to the pipe insulation. Apply evenly and finish with glass cloth.

C. High Pressure Steam Valves: Provide removable shop-fabricated fiberglass padding rated for 500°F. Line with thin wire mesh and cover with eighteen ounce high temperature woven fiberglass cloth with integral Velcro strap fasteners.

2.05 DUCTWORK INSULATION

A. Materials:

1. Flexible Glass Fiber: ASTM C553, formaldehyde-free flexible blanket.
 - a. Installed 'K' Value: 0.27 BTU-inch per hr-square foot-degree F at 75°F.
 - b. Density: 0.75 pounds per cubic foot.
 - c. Vapor Barrier Jacket: Aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft paper, secured with 2-inch wide UL listed pressure sensitive tape and outward clinched expanded staples and vapor barrier mastic as needed. Maximum vapor barrier perm rating shall not exceed 0.02 perms.

2. Rigid Glass Fiber: ASTM C612; rigid board.
 - a. Installed 'K' Value: 0.23 BTU-inch per hr-square foot-degree F at 75°F.
 - b. Density: 6.0 pounds per cubic foot.
 - c. Vapor Barrier Jacket: Aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft paper, secured with 2-inch wide UL listed pressure sensitive tape and outward clinched expanded staples and vapor barrier mastic as needed.

3. Canvas Jacket: UL listed fabric, 6 ounces per square yard, plain weave cotton treated with dilute fire retardant adhesive.
4. Covering for outdoor ducts:
 - a. Aluminum Jacket: 0.016-inch thick sheet, stippled finish, with longitudinal slip joints and 2 inch laps.
 - b. Ultra-violet light resistant painted polyvinyl chloride covering with joints secured and sealed with adhesive.

B. Ductwork Insulation Schedule:

| Service | Material | Thickness (inches) |
|--|----------------------|-----------------------------|
| Exhaust ducts within 10 feet of exterior openings | Flexible glass fiber | 1½ |
| Exhaust ducts exposed to outdoor air; ventilation equipment casings | Flexible glass fiber | 1½ |
| Supply ducts (cooling and heating systems) | Flexible glass fiber | 1½ (min. R value of 4.2) |
| Supply and return ducts in unconditioned spaces (attics, outdoors, crawlspaces, equipment rooms) | Rigid glass fiber | 2 (min. R value of 8.0) |
| Combustion air ducts | Rigid glass fiber | 2 |
| Outside air intake ducts | Rigid glass fiber | 2 |
| Supply plenums (cooling and heating systems) | Rigid glass fiber | 2 (min. R value of 8.0) |
| Return and relief ducts in mechanical rooms | Rigid glass fiber | 2 (min. R value of 8.0) |

- C. Wherever external duct insulation is specified and internal acoustic treatment of equivalent insulating effect is also required by the Drawings or Specifications for the same location, the external insulation may be omitted.

2.06 EQUIPMENT INSULATION

A. Materials:

1. Flexible fiberglass blanket: ASTM C612.
 - a. Installed 'K' Value: 0.24 at 75°F.
 - b. Maximum Service Temperature: 450°F.
 - c. Density: 6.0 pounds per cubic foot.

- d. Vapor Retarder Jacket: Aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft paper, secured with UL listed pressure sensitive tape and outward clinch expanding staples and vapor barrier mastic as needed. Maximum vapor barrier perm rating shall not exceed 0.02 perms.
2. Rigid fiberglass Board: ASTM C612.
 - a. Installed 'K' Value: 0.23 BTU-inch per hr-square foot-degree F at 75°F.
 - b. Maximum Service Temperature: 450°F.
 - c. Density: 6.0 pounds per cubic foot.
 - d. Vapor Retarder Jacket: Aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft paper, secured with UL listed pressure sensitive tape and outward clinch expanding staples and vapor barrier mastic as needed. Maximum vapor barrier perm rating shall not exceed 0.5 perms.
 - e. Facing: 1 inch galvanized hexagonal wire mesh stitched on one face of insulation. [optional]
 3. Rigid fiberglass Board: ASTM C612; rigid, noncombustible.
 - a. Installed 'K' Value: 0.23 BTU-inch per hr-square foot-degree F at 75°F.
 - b. Maximum Service Temperature: 850°F.
 - c. Density: 3.0 pounds per cubic foot.
 - d. Facing: 1 inch galvanized hexagonal wire mesh stitched on one face of insulation.
 4. Hydrous Calcium Silicate: ASTM C533; rigid molded block.
 - a. Installed 'K' Value: 0.40 BTU-inch per hr-square foot-degree F at 300°F.
 - b. Maximum Service Temperature: 1200°F.
 - c. Attachment: Insulation shall be securely banded in place, tightly butted, joints staggered and secured with 16 gauge stainless steel wire or ½ inch x 0.015 inch galvanized steel bands on 12 inch maximum centers for large areas.
 5. Elastomeric Foam: ASTM C534 flexible cellular elastomeric, molded or sheet.
 - a. Installed 'K' Value: 0.27 BTU-inch per hr-square foot-degree F at 75°F.
 - b. Maximum Service Temperature: 220°F.
 6. Apply the vaporseal board by mechanical fasteners such as Graham pins and speed washers. Seal joints with an adhesive, as approved and reinforced with a glass cloth membrane over vinyl mastic, or self-sealing matching tape. Cover pinheads with adhesive, as specified. If vaporseal board is wired, use sheet metal edges to protect the corners of the board from the wire. Seal edges and joints.
 7. Enclose removable covers or heads for equipment, (such as coolers, strainers, heat exchangers and pumps) in aluminum sheet metal boxes for easy removal with fiberglass board applied to inside of sheet metal boxes of thickness as described above. Provide lifting handles for removal of boxes.
 8. Install equipment insulation in accordance with manufacturer's instructions.
- B. Equipment Insulation Schedule:

| Service | Material | Thickness (inches) |
|---------|----------|--------------------|
|---------|----------|--------------------|

| Service | Material | Thickness (inches) |
|--|--|--------------------|
| Hot water, chilled water and glycol expansion tanks and fill tanks, shell and tube heat exchangers, air separators, chemical bypass feeder | Flexible glass fiber | 2 |
| Glycol and chilled water pumps and plate heat exchangers | Glass fiber board | 2 |
| Chiller evaporator and connections | Elastomeric foam | 1½ |
| Breeching | Calcium silicate, non-combustible rigid fiberglass board | 4 |
| Exposed supply fans (cooling systems) | Glass fiber board | 2 |

PART 3 – EXECUTION

3.01 EXAMINATION AND PREPARATION

- A. Verify that ductwork has been tested for leakage in accordance with Section 23 31 00: Ductwork before applying insulation materials.
- B. Verify that all surfaces are clean, dry and free of dirt, duct, debris, moisture or foreign material.

3.02 INSTALLATION

- A. Install materials in accordance with manufacturer's recommendations, building codes and industry standards.
- B. Verify piping has been pressure tested as specified in Section 23 21 13: Piping and Accessories before applying insulation materials to pipe joints.
- C. Continue insulation and vapor barrier through penetrations.
- D. Piping, Valve and Accessories Insulation:
 1. Locate insulation and cover seams in least visible locations where exposed.
 2. Neatly finish insulation at supports, protrusions, and interruptions.
 3. Provide insulated pipes, fittings, valves and accessories conveying fluids below ambient temperature with continuous vapor retarder jackets with self-sealing laps. Insulate complete system and provide molded flexible polyvinyl chloride jacket for all fittings and valves. Vaporseal all jacket seams.
 4. For insulated pipes, fittings, valves and accessories conveying fluids above ambient temperature, secure jackets with self-sealing lap or outward clinched, expanded staples. Bevel and seal ends of insulation at equipment, flanges and unions.
 5. Protect pipe insulation at hangers, guides, and rollers with 20 gauge galvanized metal shields, one-third the insulation circumference in width and minimum 6 inches in length up to 4 inch pipe size, 12 inches in length on pipes 5 inch and larger, on the outside of the insulation and vapor barrier or jacket. Center shield on hanger and hold shield in place by straps or by manufactured centering tabs or channels on the shield itself. Do not pierce the insulation with hangers.
 6. Provide insert between support shield and piping. Fabricate of calcium silicate or other heavy density non-deforming insulating material suitable for temperature. Length of insulation inserts shall match support shield length as specified.
 7. For exterior applications or locations where abrasion or damage may occur, provide weather protection jacket. Insulated pipe, fittings, accessories joints, and valves shall be covered with ultra-violet light resistant painted polyvinyl chloride or aluminum jacket. Jacket seams shall be located on bottom side of horizontal piping.

8. Apply prefabricated sectional insulation for straight pipes neatly fitted around the piping, and sealed with adhesive. Apply adhesive to only one side of each joint and not to pipe surface.
9. Seal all joints with BF 30-35 fire resistant vapor barrier mastic. Oversized pipe sections or board type insulation may be used to fabricate and install insulation around pipe specialties. All void spaces shall be firmly filled with flexible insulation to support oversized pipe insulation.
10. Secure sectional insulation with 0.02 inch thick by ½ inch wide aluminum bands manufactured by Childers, or Thomas & Betts "TY-RAP" nylon ties, on 24 inch centers for pipe sizes 2 inches and larger. Install at least two (2) bands per section of insulation.
11. Insulate chilled water, ~~brine, glycol,~~ refrigerant and domestic cold water vertical riser support clamps.
12. Insulate and thoroughly vapor seal control valve bodies where the valve actuator penetrates the insulation.
13. Thoroughly vaporseal the ends of all chilled water, ~~brine,~~ domestic cold water ~~of glycol pipe,~~ valve and fitting insulation sections to prevent condensation from wicking between sections.
14. Replace any self-sealing insulation or lap that is found to be not sealing properly. Do not use staples to secure the insulation or coverings.
15. Thermal Insulation for Diesel Engine Exhaust Piping:
 - a. Insulate entire diesel engine exhaust pipe system from the flanged engine connection(s) to outside the building, with three layers of 1½ thick hydrous calcium silicate, installed over spacers to allow a 1-inch air space between pipe and insulation. Include the silencer and all flexible pipe connections.
 - b. Stagger joints for the first, second and third layers.
 - c. Apply aluminum jacket (ASTM B209) over outer layer of insulation as specified.
 - d. Insulated exhaust silencer in the same manner as the exhaust piping.
 - e. Wrap or pack all protrusions through the insulation with refractory fiber. Seal all chips, joints and cracks.
 - f. Provide expansion joints in the insulation and aluminum jacket as recommended by the manufacturer to allow for movement of the flexible pipe connections, and differential expansion between the exhaust pipe, insulation and jacket.

E. Equipment Insulation:

1. Apply insulation as close as possible to equipment by grooving, scoring, and beveling insulation, if necessary. As required, secure insulation to equipment with studs, pins, clips, adhesive, wires, or bands.
2. Fill joints, cracks, seams, and depressions with bedding compound to form smooth surface. On cold equipment, use vapor retardant cement.
3. Provide cold equipment containing fluids below ambient temperature with vapor retardant jackets.
4. For insulated equipment containing fluids above ambient temperature, provide jacket with or without vapor barrier.
5. Cover insulation with metal mesh and finish with ½ inch thick insulating cement, or aluminum jacket.
6. Do not insulate over sight glasses, visual level or flow indicators, nameplates or ASME stamps. Bevel and seal insulation around these items.
7. When equipment with insulation requires periodic opening for maintenance, repair, or cleaning, install insulation in such a manner that it can be easily removed and replaced without damage to insulation or vapor barrier.
8. Insulate boiler stacks and breechings with calcium silicate wired over 1 inch high rib lath.
9. Hot equipment insulation shall be covered with ½ inch thick insulating cement over copper clad hexagonal wire.

10. Cold equipment insulation shall be covered with ½ inch thick insulating cement over vaporseal mastic and copper clad hexagonal wire.

F. Ductwork Insulation:

1. Provide insulated ductwork conveying air below ambient temperature with continuous vapor retardant jacket. Seal all vapor retardant jacket seams, punctures, tears and penetrations with UL listed tapes or vapor retardant adhesive.
2. Provide insulated ductwork conveying air above ambient temperature with or without vapor retardant jacket. Where service access is required, bevel and seal ends of insulation.
3. Continue insulation through non-fire-rated walls, sleeves, hangers, and other duct penetrations.
4. The underside of ductwork 24 inches or greater shall be secured with mechanical fasteners and speed clips spaced approximately 18 inches on center. The protruding ends of the fasteners shall be cut off flush after the speed clips are installed, and then, when required, sealed with the same tape as specified above.
5. For exterior applications, provide internal duct insulation.

END OF SECTION

SECTION 23 08 01

GENERAL MECHANICAL STARTING AND TESTING REQUIREMENTS

PART 1 – GENERAL

1.01 GENERAL

- A. Prior to starting, testing, balancing, adjusting and cleaning processes, verify with Architect any tests required to be witnessed. Provide sufficient notice to Architect prior to commencement of procedures.
- B. Architect shall be allowed to witness all testing, adjusting, starting, balancing and cleaning procedures.
- C. Assume all costs associated with starting, testing, balancing and adjusting, including the supply of testing or cleaning medium.

1.02 MANUFACTURER'S RECOMMENDATIONS

- A. Prior to starting equipment or systems, obtain and review manufacturer's installation, operation and starting instructions. Read in conjunction with procedures specified herein.
- B. Use manufacturer's and supplier's starting personnel where required to maintain validity of manufacturer's warranty.
- C. Compare installation to manufacturer's published data. Record discrepancies. Correct deviations detrimental to equipment performance prior to starting equipment.

1.03 AUTHORITIES HAVING JURISDICTION

- A. Several processes involved in starting procedures defined in this section may be duplications of authorities verification. To facilitate expedient turnover of building, arrange for authorities to witness these procedures.
- B. Obtain certificates of approval, acceptance and comply with rules and regulations of authorities having jurisdiction. Include copies of certificates with starting reports.

1.04 USE OF INSTRUMENTS SUPPLIED UNDER CONTRACT

- A. Use equipment supplied for this project testing, balancing and adjusting. Ensure equipment is properly calibrated and is proven to be in good working condition.
- B. After proper calibration:
 - 1. Use probe type flow meter and fittings supplied for this project to verify flows and volumes.
 - 2. Use thermometers and pressure gauges supplied for this project to verify temperatures and pressures.
 - 3. Use the airflow measuring stations to verify airflows.
- C. Provide calibration histories for each instrument. Recalibration of use of other instruments will be required if accuracy of readings is questioned by Architect.

1.05 CONTRACTOR TESTING INSTRUMENTS

- A. Provide two-way radios and ladders as required to complete the program as outlined in this specification.

- B. Provide all safety equipment required for personnel involved in the starting, testing, balancing and adjusting program.
- C. Provide listing of equipment and instruments, which will be used in starting, testing, balancing and adjusting mechanical equipment for approval and review by Architect.
- D. Equipment used for starting, testing and adjusting and balancing shall meet the following minimum tolerances:

| Device | Range | Accuracy |
|----------------------|-------|----------|
| Air Temperature | | |
| Hydronic Temperature | | |
| Air Pressure | | |
| Hydraulic Pressure | | |
| Air Velocity | | |
| Sound Meter | | |
| Humidity | | |

PART 2 – PRODUCTS

NOT USED

PART 3 – EXECUTION

NOT USED

END OF SECTION