SECTION 23 00 00

HVAC INTRODUCTION

PART 1 – GENERAL

A. OVERVIEW

1. This guideline specification is for the Consulting Engineers and outlines minimum requirements for the District. The Consulting Engineer should apply these guidelines consistent with the budget constraints. The Consulting Engineer must select among the mechanical systems, size and specific equipment and materials within the budget and design limits. The guidelines are based upon considerable experience with the purpose of providing the best values for the available money.
2. Sections of these guidelines include specific specification requirements in addition to design requirements. The Consulting Engineer shall review these guidelines and incorporate specific specification requirements as needed to meet specific project requirements.

B. DESIGN
1. The Consulting Engineer is required to provide a complete and workable design. The consulting Engineer is responsible and accountable for his/her work. If in the opinion of the Consulting Engineer any portion of these guideline specifications or system performance function will not be complied with, the Engineer with notify the District in writing.

C. SUBMITTALS AND O&M MANUALS
1. Consultant shall pay particular attention to the submittals and O&M Manual requirements. In addition to O&M manual data, provide all performance data, including Fan curves, pump curves, electrical characteristics, complete nomenclature, list all options furnished with equipment and equipment startup reports.

D. RESTRICTIONS AND CRITICAL CRITERIA
1. Building Design: Architectural and engineering design shall accommodate the largest and heaviest equipment listed. This shall include structural loading, mechanical service clearances and provisions for replacement of equipment.
2. Coordination: Coordinate between Fire Alarm, Electrical, Temperature Control and mechanical for combination fire/smoke and smoke dampers, including actuator type. Provide in the coordination schedule these actuators as a specific line item. The control of the fire/smoke and smoke dampers shall be by Electrical.

E. DISTRICT REVIEW
1. The review of the documents by the District is intended to assist the Consulting Engineer to comply with the guideline specification. The District’s review does not relieve the Consulting Engineer of the responsibility, accountability, completeness, and workability of the design.
2. Review Policy: Documents reviewed by the District shall be prepared in the form of red-lined plans and annotated specifications. The Consulting Engineer shall then review these documents.
3. Notification of non-compliance: When any portion of the guideline specifications will not be met, the Consultant shall notify the School District in writing.
4. No deviations to the Guideline Specification shall be accepted after final review.

END OF SECTION

SECTION 23 00 01

MECHANICAL AND ELECTRICAL COORDINATION

PART 1 – GENERAL

A. Provisions of the General Conditions, Supplementary Conditions and Division 1 – General Requirements, and applicable provisions elsewhere in the contract documents that apply to the work of Divisions 21 through 23.
B. Check and review the Electrical and Mechanical Drawings and Specifications to assure coordination with Divisions 21 through 23 and 26 through 28. Any errors and/ or omissions noted between Divisions 21 through 23 and 26 through 28 shall be brought to the attentions of the Architect for his decision.
C. The Divisions 21 through 23 Contractor(s) shall verify electrical service provided by the Electrical Contractor before ordering any mechanical equipment requiring electrical connections. Provide submittals for all mechanical equipment to Divisions 26 through 28 Contractor(s). Final responsibility for properly coordinating the electrical work of this Section belongs to the Divisions 21 through 23 System Contractor(s) performing the work which requires electrical power.
    1. It shall be the responsibility of the Divisions 21 through 23 Contractor(s) to transmit to the General Contractor prior to starting work, all changes of electrical characteristics which result from any substitution of equipment. Any and all charges for such changes shall be the responsibility of the Divisions 21 through 23 Contractor(s) performing the work.

PART 2 – DESCRIPTION

A. Responsibility: All motors and controls shall be furnished, set in place, and wired in accordance with the following schedule.

ITEM	FURNISHED BY	SET BY	POWER WIRING	CONTROL WIRING
Manual Operating & Speed Switches, (carrying load currents) (see notes 3&4	MC	EC	EC	EC
Control Relays & Transformer (See Note 2)	TC	TC	EC	TC
Interface of Mechanical Systems & Devices with Fire Alarm System	EC	EC	EC	EC
Thermostats (Line Voltage) see Note 6	TC	TC	EC	EC
Temperature Control Panels (see Note 9a)	TC	TC	EC	TC
Fire & Smoke Detectors including Relays for Fan Shutdown (see Note 7&8)	EC	EC	EC	EC
Smoke Dampers and Combination Fire Smoke Dampers (see Note 7)	MC	MC	EC	EC
Motor & Solenoid Valves, Damper Motors, Control Valves, Fan Interlocking, Wiring, Low Voltage Thermostats	TC	TC	TC	TC
Freezestats, Aquastats TC Flow Switches	TC	MC	--	TC
Pushbutton Stations & Pilot Lights (manually operated Switches not carrying load currents) (see Note 3)	EC	EC	--	MC
Boiler & Water Heater Controls Including F.I.A. Gas Train	MC	MC	EC	TC
Temporary Heating Connect	MC	MV	EC	TC
Heat Type	EC	EC	EC	EC
Variable Frequency Drives	MC	EC	EC	TC

MC= Mechanical Contractor

Under Divisions 21 thought 23 Contractor who furnishes the work.

EC= Electrical Contractor

Under Divisions 26 through 28 Contractor who furnishes the work.

TC= Temperature Control Contractor

Under Division 23 09 00 Contractor who furnishes the work.

Notes:

1. All starters shall be furnished under Division 21 through 23 and shall be complete with O.L. heaters and shall conform to NEC and NEMA requirements.
2. Control relays and control transformers shall be furnished under Division 23 except where furnishing such items are specifically required under Division 26 through 28 Specifications and/or drawings.
3. Push button stations carrying full load current are to be wired under Division 26 through 28 of the work.
4. Exhaust fans: The electrical Contractor under Division 26 through 28 of the work will furnish and install circuits, feeders and disconnect switches, and make all connections to motors and controls. Where exhaust fans are switched with lights, a two-pole toggle switch will be provided by the Electrical Contractor under Divisions 26 to 28. Where exhaust fans are controlled by sixty (60) minute timer switches, electrical contractor shall provide and install the switch(es). Where exhaust fans are interlocked with other mechanical equipment, Temperature Control Contractor under Division 23 will furnish the interlock wiring.
5. If disconnect switches are furnished as part of factory wired equipment, wiring and connections only by EC.
6. If float switches, line thermostats, time switches, etc., carry the FULL LOAD CURRENT to any motor, or heating element or other similar item, Temperature Control Contractor under Division 23 shall furnish them. They shall be set in place and connected under the Electrical Division, except that where such items are an integral part of the mechanical equipment or directly attached to ducts, piping, etc., they shall be set in place under the MC and connected by the EC. If they do not carry the FULL LOAD CURRENT to any motor, they shall be furnished, set in place, and wired under Division 23.
7. Wiring from alarm contacts to alarm system by EC, all control function wiring by TC. Smoke dampers and combination fire smoke damper actuators shall be 110 Volt.
8. Fire and smoke detectors in ductwork on mechanical equipment are mounted under MC. All other are mounted under EC. Locations to be determined by EC (Fire Alarm Sub).
    a. Electrical Contractor shall coordinate quantity and location of mechanical control panels with mechanical plans and specifications and with Mechanical Contractor. Provide a 120 Volt, 1-phase dedicated circuit from each control panel on group of control cabinets to the nearest panel board of correct voltage characteristics.

    b. Connections: Connections to all controls directly attached to ducts, piping and mechanical equipment shall be made with flexible connections.

9. Mechanical Contractor shall not fabricate ductwork until he has inspected the space in which the ductwork will be installed, coordinated the location of ductwork with the light fixtures to be installed by the Electrical subcontractor, and assured himself that all ductwork will fit the space provided. Electrical Contractor shall transmit final approved shop drawings and product data showing sizes, heights and locations of light fixtures to the General Contractor and Mechanical Contractor to properly allow this coordination to take place. Also transmit for

coordination purposes the shop/layout to allow proper installation of mechanical and electrical equipment in mechanical and electrical rooms and other such areas.

END OF SECTION

SECTION 23 00 02

HVAC DESIGN CRITERIA AND SYSTEMS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. General Mechanical Systems, Standards and Design Criteria.

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Adhere to the most recent edition of the codes and standards listed in Sections 21, 22 and 23. Together with the latest revisions, supplements, and amendments. Should a conflict exist between the guide spec and codes or standards, the Consultant shall notify the District.
   2. Ventilation
      a. Comply with ANSI/ASHRAE 62-2010 “Ventilation for Acceptable Indoor Air Quality”, or as required by most recent adopted mechanical code.
   3. Machine Rooms
      a. Comply with IMC and ASHRAE Standards 15 – 1992. Emphasis shall be placed on:
         1. Oxygen deprivation sensor for A1 refrigerants or a refrigerant sensor for B1.
         2. Mechanical ventilation.
         3. Purge and relief valve.
         4. Equipment room alarm.
   4. Accessibility
      a. All control devices shall be installed in a readily accessible location as defined in the current edition of the NEC Chapter 1, article 100.
   5. Renovation of Existing Buildings
      a. Confer with the District prior to design of mechanical systems.
   6. Design Criteria
      a. Temperature
         1. Temperature outside:
            i. Cooling – (95° F db/ 59° F wb)
            ii. Heating – (-10° F)
         2. Temperature Inside Occupied Mode: (General)
            i. Cooling – 74°F (± 2.0° F)
            ii. Heating – 71°F (± 2.0° F)
         3. Temperature inside – Unoccupied Mode: (General)
            i. Cooling – none
            ii. Heating – 65° F
      b. Ventilation
         1. Comply with ANSI/ASHRAE standards 62.1-2010 Ventilation for acceptable Indoor air Quality and ANSI/ASHRAE/IESNA Standard 90.1-2010, Energy Standard for Buildings, Expect Low-Rise Residential Buildings. Design ventilation systems to meet or exceed the minimum outdoor ventilation rates as described in the ASHRAE standard. The impact of the ventilation rates on energy use and indoor quality shall be balanced to optimize energy efficiency and occupant health. Use CO2- based demand-controlled ventilation to reduce the total supply of outdoor air during periods of reduced occupancy. Use the ASHRAE 62 User’s Manual for detailed guidance on meeting the referenced requirements. The number of occupants for each space to be verified the with Owner by the Engineer/Architect.
         2. Ventilation shall be designed as noted above and include requirements mandated by most recently adopted mechanical code and energy conservation code.
      c. Background Sound Levels:

1. Comply with methodology listed in the 2011 HVAC Applications Handbook, Chapter 47, on Sound and Vibration Control to achieve RC levels listed below.
2. Classrooms
    i. NC – 25 to 30(N)
    ii. RC – 25 to 30
    iii. dBA – 45- 50
3. Gymnasiums and Cafeterias
    i. NC – 30 to 35 (N)
    ii. RC – 30 to 35
4. Offices and Conference Rooms
    i. NC – 25 to 35(N)
    ii. RC – 25 to 35
5. Auditoriums and pools: design criteria by Acoustic Specialist

d. Exterior Sound Levels:
    1. Refer to 200548 for additional requirements.
    2. For equipment located outdoors comply with local noise level requirements as defined by local jurisdiction and code official. Review equipment sound power levels with District Project Manager for specific requirements for sound power levels in noise critical areas.
    3. Identify specific sound power requirements for sound power levels on construction documents including measurement distance or location, specific reflective considerations such as walls and enclosures, and specific sound power reduction methods of attenuation.
e. Zone control: all occupied spaces shall have individual room control.
f. All new mechanical systems shall include economizer functions. Air side economizer functions shall be included for all air handling systems 5-tons (nominal) and above. Review with the District for chilled water plant economizer options.

7. Energy Efficiency
    a. At minimum comply with design standards outlined in ASHRAE Standard 90.1.
    b. For new facilities, additions, and major remodeling projects, the design team may be directed to coordinate and work with Xcel Energy and participate in Xcel's Energy Design Assistance (EDA) program.
    c. For all projects including equipment replacements, the design team shall provide design compliant with Xcel Energy's rebate program. The design team shall work with Xcel energy and the District to outline specific requirements for the scope of work. Review with the District for electrical and natural gas services for which rebate program to incorporate.
    d. The design team shall assist the contractor in applying for and processing the documentation necessary for the Xcel Energy rebate program.

C. DESIGN PARAMETERS

1. The primary purpose of ice storage is to avoid excessive electrical demand. The design goal is for the increase capital cost of the thermal storage system to be offset by the utility savings to the School District. Since each building is different and utility rate structures may change, it is the responsibility of the Engineer to determine whether the system should have full or partial storage capability. Engineer to coordinate with local utility company for all rebates. The system design should provide a positive payback in less than 10 years based upon the current rate structure.

2. Central Cooling Plant: For Buildings with chilled water systems which do not use storage systems, the chiller(s) shall be selected to operate at a 10 to 12° F Delta T and the chilled water coils for a 10 to 12° F Delta T. The system chilled water pump shall be sized to accommodate the entire connected load. Single chiller systems shall be configured with reverse return, and variable flow primary. Variable flow primary shall reduce flow in the

system to30% total connected load or chiller minimum whichever is greater. Multiple chiller systems shall utilize primary secondary configurations with constant flow primary pumps and variable flow secondary pumps. Configure chilled water plant with variable flow secondary pumping to reduce flow to 30% of connected load. Chiller operation shall be such that a single chiller may operate during low load periods.

3. For Middle Schools and High Schools, the chilled water piping system shall use VFD's for chilled water pumps in the primary chilled water loop. Both 2-way and 3-way valves shall be used. The minimum flow rate shall not be less than 30% of the total connected load, as required by the international energy conservation code, or chillers(s) required minimum whichever is greater. The primary chilled water pump shall be sized to accommodate the entire connected load.
4. For all buildings, the primary HW loop shall be reverse return with VFD's for HW pumps. Systems shall be designed to use 2-way and 3-way valves. The minimum water flow shall be 30% of maximum connected load, or as required by the international energy conservation code. The primary heating water pump shall be sized to accommodate the entire connected load.
5. Boilers:
    a. Non-Condensing Boiler Plants: Each boiler shall have a dedicated (BCP) boiler circ. pump. BCP capacity shall match the boiler output Delta T and design. The capacity of each primary HWP shall match the total connected load. Boilers shall be piped in reverse-return method with full pipe size by-pass with isolation valves for each boiler. Each boiler shall be furnished with two low water cut-off safety switches. Boilers for new construction shall be condensing type. For remodel work which involves boiler replacement, the Engineer shall review the existing heating system and ascertain if it feasible to use condensing boilers.
    b. Condensing Boiler Plants: Condensing boiler plants shall utilize a variable flow primary system incorporating two variable flow primary pumps each sized to match the building connected load. Boiler system piping shall be reverse return to equalize flow through the boilers. Each boiler shall be furnished with a low water cut-off safety switch.

D. MECHCANICAL SYSTEMS (IN ORDER OF PREFERENCE) – ELEMENTARY SCHOOLS
    1. System No. 1 (Base system)
        a. Major components: Air cooled liquid chiller multiple indoor VAV (variable air volume) air handling units for multi-zone areas, and SZVAV (single zone vav) for large single spaces such as auditoriums, gymnasiums, and cafeterias, two gas fired condensing type boilers with power burners, DX split system (for administration), direct digital temperature control system.
        b. Air Side: All AHU's shall have full air side economizer capability. For building with crawl spaces, AHU's will be located in crawl spaces. Coordinate with Architect to provide adequate space for service and equipment replacement.
            1. Separate VAV AHU with both chilled water and DX coils shall serve the administration area. Related condensing unit shall be located in the crawl space. Provide individual VAV terminal unites (TU's) with HW heating coils for room control.
            2. SZVAV AHU shall serve a single space such as the multi-purpose room. Unit shall be designed to maintain space temperature by modulating supply air volume and discharge air temperature to meet space loads.
            3. VAV AHU's shall serve the remainder of the school. Provide individual VAV TU's with hydronic heating coils for room control.
        c. Mechanical cooling: Chiller shall provide chilled water for the entire school. During periods when only administration area is occupied, the DX system shall provide cooling for the AHU. To minimize noise concerns, the air-cooled liquid chiller will be carefully

located on the site. Consideration shall be given to locating the chiller below grade in its own enclosure, if a suitable above grade location is not available.

d. Heating
    1. Two gas fired condensing type boilers shall provide hot water for building heating. Each boiler to be sized to accommodate 67% of the total building heating load.
    2. Provide two heating water pumps. One pump shall be the primary pump, and the second pump shall be the stand-by pump. Either pump to be sized to accommodate the total conned load.

e. Air distribution: For classrooms, use conventional overhead supply distribution system.

E. MECHANICAL SYSTEMS - MIDDLE SCHOOLS
1. System No.1 (Base system)
    a. Major components: water or air cooled liquid chiller, cooling tower, multiple indoor VAV (variable air volume) air handling units for multi-zone areas, and SZVAV (single zone vav) for large single spaces such as auditoriums, gymnasiums, and cafeterias, two gas fired condensing type boilers with power burners, DX split system (for administration), direct digital temperature control system.
    b. Air Side: All AHUs shall have full air side economizer capability. For buildings with crawl spaces; AHU's, water cooled chiller and ice storage system, will be located in the crawl spaces. Coordinate with Architect to provide adequate space for service and equipment replacement.
        1. Separate VAV AHU with both chilled water and DX coils shall serve the administration area. Related condensing unit to be in the crawl space. Provide individual VAV terminal units (TU's) with HW heating Coils for room control.
        2. SZVAV air handling shall serve the multi-purpose rooms, gymnasiums, auditoriums, etc. Unit shall be designed to maintain space temperature by modulating supply air volume and discharge air temperature to meet space loads.
        3. VAV air handling units shall serve the remainder of the school. Provide individual VAV TUs with heating coils for room control.
    c. Mechanical Cooling: Chiller shall provide chilled water for the system which serves the entire school. During periods when only the administration area is occupied, the DX system shall provide cooling for the AHU. Due to noise concerns, the air-cooled liquid chiller may have to be located below grade in its own enclosure.
    d. Heating
        1. Two or three gas fired condensing type boilers shall provide hot water for building heating. If two boilers are used, each boiler shall be sized to accommodate 67% of the total building heating load. If three boilers are used, each boiler shall be sized to accommodate 35 to 45% of the total building heating load.
        2. Provide two main heating water pumps. One pump shall be the primary pump, and the second pump shall be the stand-by pump. Either main pump shall be sized to accommodate the total connected load. Arrange boiler piping to be reverse return. Where required for three boilers provide boiler isolation valves to prevent circulation of un-heated water through disabled boiler. Isolation valves shall be interlocked with boiler to open whenever boiler is enabled, and closed when boiler is disabled. Valve shall operate through boiler controls and remain open for a minimum of 5 minutes after boiler is disabled to prevent boiler overheating.
    e. Air distribution: For classrooms, use conventional overhead supply distribution system.
2. System No.2 same as System No.1, except that ice storage system is added.

F. MECHANICAL SYSTEMS – HIGH SCHOOLS
1. System No. 1 (Base System)

a. Major components: Two water cooled liquid chillers, cooling tower, multiple indoor CV (constant volume) and VAV (variable air volume) air handling units, two gas fired condensing type boilers with power burners, DX split system, direct digital temperature control system.
b. Air Side: all AHUs shall have full air side economizer capability. For buildings with crawl spaces, all AHU's, water cooled chillers will be in the crawl spaces. Coordinate with Architect to provide adequate space for service and equipment.
    1. Separate VAV AHUs with chilled water: Provide individual VAV terminal units (TU's) with HW heating coils for room control.
    2. CV air handling shall serve that multi-purpose rooms, gymnasiums, auditoriums, etc...
    3. VAV air handing units shall serve the remainder of the school. Provide individual VAV TUs with heating coils for room control.
c. Mechanical Cooling: Chillers shall provide chilled water for the entire school, except for the administration area which shall be served by a single package DX RTU.
d. Heating
    1. Three gas fired boilers shall provide hot water for building heating. If three boilers are used, each boiler shall be sized to accommodate 35 to 45% of the total building heating load.
    2. Provide two main heating water pumps. One pump shall be the primary pump, and the second pump shall be the stand-by pump. Either main pump shall be sized to accommodate the total connected load. Arrange boiler to piping to be reverse return. Where required for three boilers provide boiler isolation valves to prevent circulation of un-heated water through disabled boiler. Isolation valves shall be interlocked with boiler to open whenever boiler is enabled, and closed when boiler is disabled. Valve shall operate through boiler controls and remain open for a minimum of 5 minutes after boiler is disabled to prevent boiler overheating.
e. Air distribution: For classrooms, use conventional overhead supply distribution system.

G. SPECIAL USE AREAS AND SYSTEMS
1. Communication Room: Provide 1.5-ton DX unit with remote condenser. Larger unit may be required, Engineer to verify equipment loads. Condensing unit to be in the crawl space.
2. Kitchen/Cafeteria: Comply with the requirements of NFPA 96. Area to be served by one AHU if feasible. Kitchen to be negative with respect to all areas, except related toilet rooms. Refrigeration units for walk-in cooler and freezer shall be split system. Condensing units to be in the crawl space when available, located on roof when no crawlspace is available. Refrigeration condensing units located at grade level are discouraged unless approved by the District.
3. Kitchen Make-up Air: Avoid make-up unit, if possible, obtain make-up air from AHU which serves kitchen and cafeteria. In the event make-up air is not adequate from the AHU, use a gas fired make-up air unit for tempered air to meet exhaust requirements for grease hood.
4. Pools: The use of solar water heating panels is not recommended and shall be avoided. If energy recovery is required by adopted mechanical code, provide condenser/compressor energy recovery loop.

H. DESIGN CONSIDERATIONS
1. No AHUs shall be located above ceilings.
2. Provide isolation valves at all branch run outs, at all equipment and sections of piping.
3. Provide strainers at all control valves.
4. Do not install piping in exterior walls.

5. AHU fans shall be belt drive whenever possible, avoid direct drive fans unless approved by the District. Small equipment fans such as exhaust fans, fan coil units, and fractional HP units may be direct drive. Specify direct drive fans for fans 1/2hp and smaller, use belt drive fans for 3/4hp and larger. Direct drive fans shall include speed control or ECM motors.
6. HWS/R piping shall be reverse return. Advise Owner if Consultant wishes to design system for direct return.
7. All connections made to existing chilled water, heating water and domestic water systems shall be made with isolation valves.
8. No pumps shall be located above ceilings.
9. Digital scroll compressors are never to be selected or specified for design.
10. System water pressure losses shall be designed with energy conservation in mind. Maximum water pressure drop (without diversity) for pipe sizing shall not exceed 3 feet per 100 feet and maximum velocity (without diversity) shall not exceed 8 feet per second. Care shall also be taken to keep water pressure drop for coils, chillers, heat exchangers and control valves as low as possible.
11. System air pressure losses shall be designed with energy conservation in mind. Maximum air pressure drop for main low-pressure ductwork shall not exceed 0.08 inches per 100 feet and maximum velocity shall not exceed 1,600 feet per minute. Acoustic constraints for sound critical areas such as Stages and Auditoriums may require lower duct velocities. Maximum air pressure drop (without diversity) for medium pressure ductwork shall not exceed 0.25 inches per 100 feet and maximum velocity (without diversity) shall not exceed 2,500 feet per minute. Care shall also be taken to keep air pressure drop for coils, heat exchangers, VAV Terminal Units, fire dampers, smoke dampers, combination fire/smoke dampers and duct fittings as low as possible.

END OF SECTION

SECTION 23 00 04

MECHANICAL MATERIALS AND METHODS

PART 1 – GENERAL

A. SUMMARY – SECTIONS INCLUDES
   1. Pipe Hangers and Supports
   2. Motors and Starters
   3. Pipe Installation
   4. Pressure Testing of Piping Systems
   5. Expansion Compensation
   6. Gauges

B. REFERENCED STANDARDS
   1. ANSI B31.1
   2. IEEE-112
   3. NEMA

C. SUBMITTALS
   1. Shop Drawings:
      a. Expansion joints, pipe guide and anchor layout.
   2. Product Data:
      a. Gages
      b. Hangers
      c. Expansion Joints
      d. Thermal Hanger Shields

D. CRITICAL CRITERIA/RESTRICTRICTIONS
   1. Pipe Installation:
      a. Install piping without springing or forcing, and clear windows, doors, and other openings.
      b. Provide sufficient swing joints, anchors, expansion loops and devices necessary to permit free expansion and contraction without causing undue stresses.
         1. The Consulting Engineer shall size expansion loops.
         2. Coordinate movement of building with Soils Engineer.
      c. Shut-Off Valves: Provide shut-off valves and unions suitably located, to isolate each item of equipment, branch circuit or section of piping. Visibly mark location of concealed valves.
      d. Provide dialectic nipples (equal to Victaulic style 47) or waterways for building heating water and chiller water systems. Provide isolation valve in steel pipe near dielectric nipple.
      e. Strainers: Provide strainers at all temperature control valves.
      f. Air Vents: Provide air vents at top of all coils and at high points in hydronic system. Coin operated air vents are not acceptable.
      g. Building Heating Water System: For pipes 2” and smaller unions shall be 250LB, black malleable iron with ground joint and brass seat. Provide brass ball valve to connect to copper piping. Dielectric unions not allowed.
      h. Connections: Screw joint steel piping up to and including 2”. Weld piping 2 1/2” and larger including branch connections.
         1. Make connections to equipment and branch mains with unions.
         2. All HWS&R run outs and branches shall be top take-off at 45°, bottom take-offs not allowed.
      i. Routes and Grades:

1. Slope water piping 1”in 40’ and arrange to drain at low points.
2. On closed systems, equip low points with drain valves and hose nipples. At high points, provide collecting chambers and automatic air vents.
3. Coordinate and verify all invert elevations, whether or not shown prior to excavation and installation of interior and exterior piping.
4. Locate all drain valves and air vents of “Record Drawings”.

2. Installation of Pipe Hangers: Adequately support piping from the building structure with adjustable hangers to maintain uniform grading where required and to prevent sagging and pocketing. Providing support between piping and building structure where necessary to prevent swaying.
   a. Inserts: Specify calcium silicate pipe inserts for insulated pipe 1-1/2” and larger.
   b. Shields: Specify sheet metal shields for all piping 3/4” and larger. Shields shall be a minimum of 6” long. Shields for clevis type hangers shall be 180°, and shields for trapeze hangers shall be 360°.
   c. Specify pipe clamps for all pipes supported by trapeze type hangers.
   d. Pipe clamps shall clamp around insulation, and not to piping itself.
3. Expansion Compensation
   a. General: Provide flexible pipe connectors on pipes connected to equipment supported by vibration isolation.
   b. Expansion Loops: Provide expansion loops and offsets where required.
      1. Flexile hose type expansion loops are acceptable in lieu of hard piped expansion loops.
   c. Anchors: Securely anchor piping where indicated or where required for proper installation.
   d. Pipe Guides: Install pipe guides where indicated or where required for proper installation of expansions loops.
4. Gages:
   a. Locate bulb portion of socket in fluid flow and enlarge pipe as required so as not to restrict flow.
   b. Thermometers in insulated ducts shall have mounting flange reversed to bring mounting connections outside insulation. Thermometers to be digital, non-mercury housed.
   c. Provide thermometers and gages as follows:
      1. Provide thermometers in heating water system as follows:
         i. Heating water supply and return mains.
         ii. Boiler(s) inlet and outlet.
      2. Provide thermometers in chilled water and condenser water supply and return system mains. Exact location to be determined by the Engineer if not indicated on drawings.
      3. Provide gauges at suction and discharge of each primary chilled water pump, heating water pump and condenser water pump.
5. Equipment Bases and Supports
   a. Vibration Isolation Bases: See Section 23 05 48.
   b. Housekeeping Bases: Concrete bases are required for all floor mounted equipment provided under Division 21, 22 and 23.
6. Piping System Testing
   a. Test procedures:
      1. Heating hot water piping, condenser water piping, chilled water piping, steam and condensate return lines: 120 PSIG hydrostatic tests.
      2. Hold hydrostatic tests for a minimum of eight (8) hours without loss of pressure. Hydrostatic test pressure shall be measured at the low pint of the individual system or done being tested. Hold air tests for a minimum of one (1) hour without loss of pressure.

b. Retesting: Retest piping failing initial tests following correction of defective work. Requirements of initial tests shall apply.
c. Test Report: The test report shall contain the following and be submitted within 7 days of each test:
    1. Date, time, and place of test.
    2. Duration of test
    3. Persons responsible for testing
    4. Results of test
    5. Action taken to correct deficiency.
    6. Outside air dry bulb temperature
    7. Specific section of piping tested.

PART 2 – PRODUCTS

A. PIPE HANGERS AND SUPPORTS
    1. General: Comply with “The Code for Pressure Piping, ANSI B31.1, with Addenda 31.1 Oa-69”.
    2. Insulated Pipe Supports: Protect all insulated pipe at point of support with hanger shields. Shields shall be minimum 180° and 6” long. Protect all insulated pipe 1-1/4” and larger with thermal hanger inserts. Thermal hanger inserts shall consist of a 180 degree insert for clevis type hangers, and 360 degree insert for trapeze hangers, of high density, 100 PSI, waterproof calcium silicate or equivalent.

B. EXPANSION CONPENSATION
    1. Acceptable Manufactures
        a. Hyspan
        b. Webster
        c. Resisto-Flex
        d. Thermo-tech
        e. MetraFlex
        f. Approved Substitute
    2. Radiation Expansions Joints: Designed for 100 PSI minimum working pressure of capable of accepting one inch (1”) of pipe expansion and 1/4” of pipe contraction for a total movement of 1-1/4”.
    3. Pipe Expansion Joints
        a. Steel Piping
            1. 3” and under: Stainless steel bellows type with anti-torque devices, limit stops and internal guide. Equal to Hyspan 8500 series.
            2. Over 3”: External ring-controlled type with hydraulically formed stainless steel bellows. Equal to Hyspan 3500 Series, 850°F.
        b. Copper piping: All bronze type with two-ply bronze bellows, anti-torque device limit stops, internal guides and solder joint end.
    4. Flexible Hose Expansion Loops:
        a. Copper Piping:
            1. Copper-alloy fittings with solder-joint end connections. Bronze hoses and single-braided bronze sheaths with 450 psi at 70°F and 340 psi at 450°f ratings.
            2. Provide union at each end of expansion loops to facilitate removal of loop.
        b. Steel Piping:
            1. Carbon-steel fittings with threaded end connections for 2” and smaller, and flanged end connections for 2-1/2” and larger. Stainless steel hoses and single braid, stainless steel sheaths with 200 psig at 70°F and 145 psi at 600°
            2. Welded pipe connections at expansion loops are not permitted.

C. MOTORS AND STARTERS
1. Manufacturers:
   a. All motors shall be as manufactured by approved manufacture.
   b. ABB
   c. Baldor
   d. General Electric
   e. Lincoln
   f. Reliance
   g. Toshiba
   h. TECO – Westinghouse
   i. US Motors
   j. WEG
2. Motor 3/4 HP and larger shall be 480 Volt, Three-Phase, 60 Hertz, 1800 and/or 1,200 RPM with OPD enclosure. Motors shall be designed for quiet continuous operation with 40°C rise above ambient at full load, service factor of 1.15, copper windings, class B or F insulation.
3. Motors used with Variable Frequency Controllers shall have ratings, characteristics and features coordinated with approved by the VFD controller and manufacturer.
   a. Motor shall be designed with critical vibration frequencies outside operating range of controller output.
   b. Insulation class shall be Class H, same as Class B, except with silicone resin binders.
   c. Comply with NEMA MG 1 requirements for thermally protected motors.
   d. All motors 7-1/2hp and above which utilize VFD's shall include shaft grounding rings for motor bearing protection.
4. All motors shall have conduit connection boxes and permanently sealed prepublication ball bearings using grease for operation at -30°F. They shall open drip proof, standard NEMA frame, normal duty, and normal starting torque unless otherwise noted.
   a. The nameplate horsepower rating without consideration of the service factor shall not be exceeded at any point along the performance curve of any pump at its rated RPM.
   b. Bearings: Double shielded ball in accordance with ANSI B3.16
   c. Motor wiring: Terminate in a NEMA terminal box mounted on the motor case and of the manufactures standard size. The terminal box shall have a bolt type copper ground connector.
   d. Motors 1/2 HP or less may be split capacitor single phase with sleeve bearings or ECM type, and shall be a standard frame size and RPM, available from more than one manufacture.
   e. Ascertain and/or Engineer before ordering equipment or work.
   f. Motor efficiency shall conform to IEEE-112 and NEMA Chart 12-10.
   g. Power factor for all motors 2 HP and larger shall have a minimum power factor of 0.90. All motors shall comply with requirements outlined in most recent adopted version of the Energy Conservation Code.
5. For single phase direct drive motors specify solid state electronic speed control or ECM motor for balancing.
6. Starters for small motors without starts shall have thermal overload protection in each phase. All magnetic starts to be furnished with transformers to provide 120C control voltage. Where 120V control may be established by crossing line voltage and neutral (if available), or it is specifically indicated to be obtained by some other means, control transformers may be omitted. All motors over 10 horsepower shall have reduced voltage starters.
   a. Starters shall be Allen Bradley, Cutler-Hammer, Furnas or Square-D standard magnetic contractor-type with HAND-OFF-Auto switch, overload heaters, 120V control transformer, and single-phase protection, under voltage protection and square N.O. and N.C.

contracts for control by Division 23. NEMA enclosure appropriate for the service or 3R for wet areas.

b. Use magnetic starts for motors 3/4 HP and larger.
c. Electrical materials and methods shall be in accordance with the provisions of Division 26.

D. GAUGES
1. Temperature Gauges: Description – die-cast with baked enamel finish, digital read-out, adjustable multi-angle housing, and brass separable socket. Note: Mercury filled gauges are not allowed.
2. Pressure Gauges: Description – phenolic turret case, 4 1/2 “dial with suitable ranges, phosphor-bronze bourdon tube, corrosion resistant movement, adjustable stainless-steel pointer, 1% of full-scale accuracy, ¼“ NPT brass connection. Furnish ¼ “brass needle valve and pressure snubber with each pressure gauge.

END OF SECTION

SECTION 23 05 23

HVAC VALVES AND SPECIALTIES

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUES
   1. HVAC Valves and Specialties:
      a. Valves
      b. Specialties

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Reference Standards: Comply with applicable requirements of the following standards:
      a. Nation Certificated Pipe Welding Bureau (NCPWB)
      b. ASME Boiler Pressure Code
      c. American Water Works Association (AWWA)
      d. ANSI B31 Code for Pressure Piping
      e. Underwriters'' Laboratories, Inc. (UL)
      f. International Building Code
      g. National Fire Protection Association (NFPA)
      h. National Electrical Manufacturer's Association (NEMA)
      i. National Electrical Code (NEC)
      j. American Welding Society (AWS)
      k. American National Standards Institute (ANSI)

C. SUBMITTALS
   1. Product Data:
      a. Valves
      b. Specialties
   2. Operating and Maintenance Data:
      a. Valves
      b. Specialties

D. RESTRICTIONS/ CRITICAL CRITERIA
   1. Valves
      a. Install ball valve or butterfly valve for shut-off and isolation service, to isolate equipment, parts of system or vertical risers.
      b. Provide drain valves at main shut-off valves, low points of piping and apparatus.

PART 2 – PRODUCTS

A. VALVES
   1. Acceptable Manufactures
      a. Keystone
      b. Dezurick
      c. Nibco
      d. Grinnell
      e. Stockham
      f. Apollo
      g. Hammond
      h. Kitz

   2. General: All valves of a given type shall be of one (1) manufacture and shall be listed with the Manufactures' Standardization Society of the Valve and Fittings Industry.

3. Valve Connections:
    a. Provide Valves suitable to connect to adjoining piping as specified for pipe joints.
    b. Thread pipe sizes 2” and smaller.
    c. Flange pipe size 2½” and larger.
    d. Solder or screw to solder adapters for copper tubing.
    e. Provide butterfly valve with tapped lug body when used for isolating service.
4. Ball Valves: Bronze, full port, chrome plated bronze ball with Teflon seats, 150 WSP, 400 WOG, screwed or soldered ends. Ball valves located in steel pipe shall have stainless steel ball.
5. Butterfly Valves:
    a. 2-1/2 through 5”: Cast iron body, full-lug type, extended neck, stainless steel stems, EPDM elastomer seat, aluminum-bronze disk, lever lock handle with toothed plate and position lock. Valve shall be bubble tight up to 175 PSI. Valves shall be rated for bi-directional deal-end service to full working pressure of the valve with downstream flange removed.
    b. 6” and larger: Cast iron body, full-lug type, extended neck, stainless steel shaft, EPDM elastomer seat, aluminum-bronze disk, gear actuator with disc position indicator. Valve shall be bubble tight up to 175 PSI. Valves shall be rated for bi-directional dead-end service to full working pressure of the valve with downstream flange removed.
6. Drain Valves: Ball valve with GHT male end and chained cap.
7. Balancing Valves: Tight close-off, adjustable memory, 175 PSIGN. Eccentric valves shall be used.
8. Eccentric Valves: Corrosion resistant plug, permanently lubricated, corrosion resistant bearings, EPDM seals, 175 WOG, flanged ends, lever operator for valves 3” and smaller. Worm gear actuator for valves 4” and larger. Valves for balancing service shall have adjustable memory stops.
9. Check Valves:
    a. Swing check valves:
        1. 2” and smaller: Bronze horizontal swing disc, renewable Teflon disc, solder or screwed ends, 150 lbs. WPS, 300 WOG.
        2. 2½” and larger: Cast iron body, bronze trim, horizontal swing disc, renewable bronze and seat, flanged ends, 125 lb. WSP, 200 WOG, bolted bonnet.
    b. Spring loaded silent check valves: Cast iron body, bronze trim, spring loaded, wafer type with field replaceable EPDM seat, stainless steel springs, 125 lb. WPS.
10. Valve Operators:
    a. Provide suitable lever handle for butterfly valves.
    b. Provide chain operators for valves 4” and larger located more than 7 feet from floor in equipment rooms. Extend chains to 5 feet from floor and hook to clips arranged to clear aisles.
    c. Provide handle extensions for insulated piping.
11. Pressure Ratings: Unless otherwise indicated, use valves suitable for minimum 125 PSIG working steam pressure at 450*F and 200 PSIG non-shock cold water.

B. SPECIALTIES
1. Strainers:
    a. Acceptable Manufactures:
        1. Bell and Gossett
        2. Amtrol
        3. Taco
        4. Thrush
        5. Apollo Valves
        6. Conbraco

7. Crane Co.
8. Hammond Valve
9. Milwaukee Valve Company

2. Pressure and Temperature Relief Valves:
   a. Acceptable Manufactures:
      1. Watts
      2. Bell & Gossett
      3. McDonnell-Miller

C. BALANCING FLOW METERS
   1. Stations:
      a. Manufacturers:
         1. Gerand
         2. Flowset
         3. ITT Bell & Gossett
         4. Taco
         5. Tyco Flow Control
         6. Flow Design Inc

      b. Sized such that design flows fall within the mid-range of the meter scale, with a maximum installed pressure drop of 2.0 feet.
         1. Through 4”: Flow set combination Venturi/ball valve. Full size handle grip and memory stop.
         2. Above 4”, Factory tested accuracy shall be 2%, low loss design, sized such that designed flows fall within the mid-range of the meter scale, with a maximum installed pressure drop of 2.0 feet. One portable meter shall be turned over to the Owner.
      c. Provide a metal identification tag with chain for each installed Venturi. The tag to be stamped with the unit or zone, Venturi model number, flowrate in GPM and differential pressure.
      d. Metering stations for over 4” shall be a Venturi with a separate balancing valve.

END OF SECTION

SECTION 23 05 48

MECHANICAL NOISE AND VIBRATION

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Sound Isolating Pads.
   2. Spring type isolators.
   3. Flexible Connections
   4. Acoustical Floor, Ceiling and Wall Seals.

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. ASHRAE Guide

C. SUBMITTALS
   1. Shop Drawings and Product Data:
      a. Equipment Pads.
      b. Spring Type Isolators.
      c. Vibration Hangers.
      d. Flexible Connections.
      e. Acoustical Floor, Ceiling and Wall Seals.

D. RESTRICTIONS/ CRITICAL CRITERIA
   1. Structural Requirements: Design pad and isolator sizes for equipment loads including side loading.
   2. Acoustic Requirements: Provide and install vibration eliminators so that average noise criteria as outlined in ASHRAE guide are not exceeded.
   3. Provide vibration isolators for motor driven mechanical equipment unless specifically noted otherwise. As a minimum comply with ASHRAE Vibration Isolator Selection Guide and manufacturer's recommendations.
   4. No rigid connections between equipment and building structure shall be made that degrades the noise and vibration isolation system here in specified. Electrical conduit connections to isolated equipment shall be looped to allow free motion of isolated equipment.
   5. Base Mounted Pumps: Vibration isolator manufacturer shall furnish rectangular structural beam or channel concrete forms for floating foundations. Bases for end suction pumps shall be large enough to provide support for suction diffuser. Bases shall be equal to Mason Type K and springs shall be equal to Mason Type SLF/
   6. Flexible connectors: Only EPDM materials are acceptable. Do not use devices with exterior metal braiding.
   7. Acoustical Floor, Ceiling and Wall Seal: Where piping passes through equipment walls, floors, or ceiling, provide a split seal to minimize the passage of noise though the seal and vibration to the structure. Seals shall be equal to Mason Type SWS.
   8. Exterior Equipment Requirements: For equipment located on roofs or on grade the design professional shall ensure radiated sound levels are minimized at the property line. District shall notify the design engineer of specific sound issues at existing locations.
      a. Refer to specific sound requirements at site location, and according to local sound ordinances. Limit sound levels to 50db(A) where facilities are located in residential areas, and 65db(A) in commercial areas, where specific sound criteria are not available.
      b. Sound mitigation measures shall include:
         1. Compressor insulating sound blankets for air cooled chillers and air handling equipment.

2. Low sound or low speed condenser fans (air cooled condenser, cooling towers, air cooled chillers.
3. Specify sound enclosures where specified equipment is not available with required sound attenuation packages. Define specific sound attenuation package requirements on contract documents. Requirements shall include estimated sound power levels at property line.

PART 2 – PRODUCTS

A. VIBRATION ISOLATORS
   1. Acceptable Manufactures:
      a. Mason Industries
      b. Consolidated Kinetics
      c. Amber-Booth

END OF SECTION

SECTION 23 05 53

MECHANICAL IDENTIFICATION

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES:
   1. Markers, tags and labels for mechanical pipes and equipment.

B. REFERENCED STANDARDS (MINIMUM CRITERIA):
   1. Comply with ANSI A13.1 - Identification of Piping Systems.

C. SUBMITTALS
   1. Shop drawings
      a. Pipe identification
      b. Valve tags
      c. Equipment identification

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Piping Identification
      a. General: Identify contents and direction of flow of piping in crawlspaces, above ceilings, etc., as well as exposed to view. Provide identifying markings at valves and equipment, at terminal points and at both sides of piping passing through walls and floors. In addition, provide identifying markings at 40’ on center.
      b. Stenciled Markings: Apply after completion of finished coat of paint. Wipe pipe clean. Perform stenciled-on markings without overspray, drips, or other imperfections.
      c. Pressure Sensitive Markers: Apply in accordance with manufacturer’s recommendations. Marker adhesion will be tested for permanence. Replace any markers showing dog-ears, bubbles, or other failings.
      d. Use an arrow marker with each pipe content stencil. The arrow shall always point away from the pipe stencil and in the direction of the flow; color and height of arrow to be same as content stencil. If flow can be both directions, use a bubble-headed arrow stencil.
      e. Apply pipe stencil and arrow stencil within 3” of each valve to show proper identification of pipe contents and direction of flow.
      f. Apply the stencil to the pipe so lettering is in the most legible position. For overhead piping, apply stencil on the lower half of the pipe where view is unobstructed, so stencil can be read from floor level.
   2. Valve Identification
      a. General: Identify main water service valves, including valves located inside the building for type of service. Identify valves and cocks controlling branch mains or risers to various portions of the building as the area served. Use tags secured with brass chains.
      b. Stamp valve tags with a unique prefix to indicate system, followed by a number. (Example: CW-1, CW-2, HW-1, etc..). In general, the prefix will match the system abbreviation used on the drawings.
   3. Equipment Identification
      a. Controls: Label magnetic starters and relays on identify connecting or controlled equipment. Label manual operating switches fused disconnect switches and thermal overloads switches which have not been specified as furnished with indexed faceplates as to “connected” or “controlled” equipment. Label automatic controls, control panels, zone valve, pressure electric, electric pressure switches, relays, and starters.
      b. Pumps: Identify booster pumps as to service zones served with tags secured by brass chains. Label base-mounted pumps.

c. Storage Tanks and Heaters: Label tanks as to service. Identify the connecting pipes to each tank.
d. Fans: Label supply and exhaust fans and air handling units as to drawing code number, service and areas of zones served.
e. Fire Dampers and Combinations Fire/Smoke dampers: Identify all fire dampers and combination fire/smoke dampers and their access door by printed stencil secured to access door or a location approved by Architect.
f. Provide labels for concealed mechanical equipment located above ceilings, such as: variable air volume, terminal units, duct coils, circ pumps, in-line fans. Locate label under ceiling at tee grid of lay-in ceiling. Pressure sensitive markers may be used for this application.
g. Provide labels for all concealed isolation valves above ceilings. Locate label under ceiling at tee grid of lay-in ceiling. Pressure sensitive markers may be used for this application.

PART 2 – PRODUCTS

A. MATERIALS
1. Pipe Markers: Utilize either of the following methods:
   a. Pressure sensitive markers: Flexible film identification markers and tape, with legend size and color coding per ANSI A13.1.
   b. Stenciled markings: Use clear cut stencils and black oil base spray paint. Provide 1” high letters on small pipe sizes and 2” high on larger pipe sizes. Flow arrows shall be at least 6” long.
2. Tags: Aluminum or brass 1½” diameter with edges ground smooth. Evenly spaced and stamp letters and number into the metal surface. Provide brass chain for attachment.
3. Equipment Labels: White plastic laminate with black engraving, or standard brass strips fastened with brass screws. Pressure- sensitive embossed labels (Dymo-type) not acceptable. Provide labels to uniform size commensurate with the size of the equipment to which attached, minimum ½” high letters. Label shall identify equipment terminology to match equipment schedules and plan documentation.
4. Equipment Nameplates: Provide manufacturers equipment nameplate for all equipment. Nameplate shall be clearly visible. Nameplates located in exterior locations shall be protected from fading due to sun and elements. Nameplate shall include the following:
   a. Manufacturer Name, product name, model number, and serial number
   b. Operating capacity, operating and power characteristics, and essential data
   c. Labels of tested compliances
5. Lay-In Ceiling Identification:
   a. Self-adhesive type paper or laminate plastic tape. 3/4 inch wide and 1-1/2 inch long with pre-printed identification.
   b. Color: White background with black lettering.
   c. Label Information: Provide identification of equipment, valve, control device, or similar equipment above lay-in ceiling. Label shall include identification as noted on contract documents, or clear identification of unit above ceiling.

END OF SECTION

SECTION 23 05 93

TESTING, ADJUSTING AND BALANCING

PART 1 – GENERAL

A. GENERAL

1. Test and balance shall be contracted directly through the District.

B. SUMMARY – SECTION INCLUDES
1. Adjust and balance Water Mechanical System
2. Adjust and balance Air Mechanical System
3. Adjust and balance Domestic Water Heating Systems (as indicated)
4. Check each piece of operating equipment provided on Div. 23
5. Balancing Report

C. REFERENCED STANDARDS (MINIMUM CRITERIA)
1. Balancing Work: To be done under direct supervision of a registered professional engineer, having an experienced record of not less than five (5) years in the mechanical contracting industry, engaged in testing, balancing, and adjusting of air and hydronic mechanical systems for not less than two (2) years at a time.
2. T&B Contractor shall be contracted direct by the School District.
3. Acceptable Contractors:
   a. Midwest/Colorado Springs Inc.
   b. JPG Engineering
   c. TAB Services
   d. Griffith Eng Svcs.
   e. Jedi Balancing.
   f. Double T
   g. Complete
   h. Lawrence H Finn
   i. Air Right Inc.
   j. Richter Commissioning Group
4. Referenced Standard: Comply with AHSRAE Handbook Chapter on testing, adjusting, and balancing.
5. Warranty: The balancing agency shall provide an AABC National Guarantee Certification or NEBB equivalent. In addition, the balancing agency shall include an extended warranty thought one (1) full heating and cooling season after completion of the test and balance work, during which time the Architect at his discretion, may request a re-check of the setting of any outlet, supply air fan, exhaust fan, etc., as listed in the Balancing Report. The balancing agency shall provide technicians to assist the Architect in making any tests he may require during this period.

D. SUBMITTALS
1. Control System Coordination Reports: Communicate in writing to the controls installer all setpoint and parameter changes made, or problems and discrepancies identified during TAB that affect, or could affect, the control system setup and operation.
2. Balancing Report: At completion of work submit Balancing Report.
3. Where required for the scope of work for major mechanical equipment replacement, terminal unit replacement, or similar, provide pre-construction balance. Pre-construction balance shall include measurement of existing conditions for use as reference during final balance. Pre-construction balance shall include:
   a. Large Rooftop Air Handling Units

b. Small Rooftop Air Handling Units
c. Make-up Air Units
d. VAV/FPVAV/Fan Coil/Terminal Units
e. Hydronic balancing valves as indicated on drawings.
f. Hydronic heating/cooling pumps.
g. Hydronic heating/cooling coil flow rates.

E. RESTRICTIONS/CRITICAL CRITERIA
   1. General: Check, adjust and balance air and water systems to meet the design performance and tabulate results on acceptable forms. Minimum data to include amperage, voltage input, and thermal heater capacity of each motor, equipment nameplate data, operating speed, pressure drop across each filter bank, pressure rise across each fan and pump, CFM capacity each outlet, zone and fan, and heating or cooling capacity of each coil or element.
   2. Warranty Period Inspection: After eleven (11) months of occupancy, perform a complete report of total system analysis with full report to Architect. Put controls through normal operating cycles (do not change any calibration point).

F. STATUS OF SYSTEMS
   1. Air and water testing and balancing shall not begin until the system to be tested has been cleaned and flushed and is in full working order. Where glycol is used, it shall be installed prior to hydronic balancing.
      a. Coordinate scheduling of work with the general contractor and appropriate subcontractors. Schedule TAB work to coincide with testing and verification of control systems.
      b. Provide written notification (within 24 hours) to the general contractor, engineer, and owner or his/her representative of any component and/or system deficiencies.
   2. Review available plans and specifications for the project and make visual observations during construction to determine that required balancing devices are being installed properly, and access to them is provided.
   3. Before any air balance work is done, systems shall be checked for:
      a. Excessive duct leakage. Excessive duct leakage shall be corrected.
      b. Dirt and debris in ducts and/or air handling units (AHUs).
      c. Filters are installed and changed if they are dirty.
      d. Coil fins are clean and combed where needed.
      e. Verify motor rotation and correct if necessary.
      f. Excessive vibration. Excessive vibration shall be corrected.
      g. Equipment has been lubricated in accordance with manufacturer’s recommendations.
      h. Proper operation of automatic control and smoke dampers shall be verified.
      i. Manual control dampers, fire dampers, and air outlet dampers are wide open.
      j. Duct end caps are properly installed, and access doors closed.
      k. Grilles, registers, and diffusers are properly installed.
   4. Before any hydronic balancing work is done, the system shall be checked for:
      a. Proper cleaning and flushing have been completed; glycol installed when specified.
      b. Dirty strainers have been cleaned.
      c. Correct pump rotation has been verified.
      d. Proper control valve installation and operation.
      e. Proper system static pressure to assure a filled system.
      f. Air in system eliminated.
      g. Proper flow meter and check valve installation.
      h. Manual balancing devices, control and shut-off valves are open.
   5. Put heating, ventilating, and air conditioning systems and equipment into full operation and continue operation of same during each working day of testing and balancing.

G. For remodels and additions, TAB shall include the entire system being worked on. TAB of an extended or modified branch only shall not be accepted.

PART 2 – PRODUCTS

A. INSTRUMENTS

1. Calibration and maintenance of instruments shall be in accordance with manufacturer's standards, recommendations, and requirements of NEBB.
2. Calibration histories for each instrument shall be available for examination.

B. REPLACEMENT ELEMENTS
1. Provide replacement sheaves and replacement thermal overload elements which may be required to satisfy the actual job design conditions.

PART 3 – EXECUTION

A. AIR BALANCE
1. Balance air supply, return, and exhaust systems and record air quantities for each air device.
   a. The pilot tube traverse method for determining main duct CFM shall be used and recorded wherever possible; flow hood measurements at registers and diffusers may be totalized for branch duct quantities.
2. Air diffuser pattern shall be set to minimize objectionable drafts and noise.
3. The supply, return, and exhaust fan static pressures shall be set by the balancing firm (and the controls contractor if the systems have fan volume control).
   a. The lowest fan speed resulting in satisfactory system performance shall be determined at full design delivery. Any inlet or outlet fan volume (balancing) dampers shall be in the wide-open position, and one path presenting the greatest resistance to flow shall be fully open and unobstructed.
   b. Fan RPMs shall not be increased by more than 10 percent without prior authorization from the engineer.

4. Provide system static pressure profiles that identify pressure differences across all components of air handling units and built-up systems. Pressure drops shall be individually measured and recorded for intake and exhaust vents, hoods, louvers, manual and auto control dampers, filters, coils, evaporative coolers, fans, etc.
   a. On systems with OSA economizers, pressure drop values shall be recorded for both minimum and 100 percent OSA modes.
5. Building static pressure adjacent to entries shall be measured and recorded. Adjust systems to maintain a positive pressure of 0.05" w.c. where possible. Note any discrepancies.
6. When air balancing is done and manual dampers are set, all test holes shall be plugged, and all manual damper positions shall be marked.

B. HYDRONIC BALANCE
1. Converters: record all steam and/or water inlet and outlet temperatures, pressure drops, and flows.
2. Record inlet and outlet water temperatures of all AHU coils, unit heaters, convectors, finned tube radiation, and other heat release equipment, as well as the corresponding media flows and pressure drops.
3. Boilers: provide data for boiler operating conditions and thermal efficiencies. (Provide a copy of the independent testing agency report if the TAB Contractor does not perform testing.) The TAB Contractor shall measure water side temperatures, pressures, and flow rates if requested by owner and/or boiler testing agency.
4. Chilled water systems: measure and record chilled and condenser inlet and outlet fluid temperatures, evaporator and condenser fluid pressure drops and flows, full-load motor running voltage and amperage, chiller refrigerant pressures and temperatures.

5. DX cooling systems: record condensing unit full and part-load amperages, condenser fan(s) rotation and running amperage(s), high and low side refrigerant pressures, coil inlet and outlet air temperatures at full-load condition. Verify operation of condenser fan and head pressure controls.
6. Hydronic pumps: record flow rates, pressures, running amperage, and full-load amperage at design flow and shutoff conditions. Verify and record impeller size and shutoff head.
7. When all hydronic balancing is done, all balancing valve positions shall be marked, and the locking devices set. Control valve bypass loops (where used) shall be set with the balancing valve to provide equal flow in either mode.

C. ELECTRIC HEAT
1. Record full-load and part-load (when staged) amperage and voltage of all electric heating elements.
2. Verify that electric heat is locked out when the flow rate drops below minimum requirements.

D. SMOKE SYSTEMS
1. Test all smoke management systems per Chapter 4 of the latest version of NFPA 92A.
2. Refer to Section 230900 Controls, for smoke management sequences.
3. Leave systems in proper working order, replacing belt guards, closing access doors, closing doors to electrical switch boxes, and restoring thermostats to specified settings.

E. SYSTEM TOLERANCES
1. Allowable tolerances
   a. Tolerances of adjustment for air handling systems: ± 5 percent for supply systems and ± 10 percent for return and exhaust systems from figures shown on drawings.
   b. Tolerances of adjustment for hydronic systems: ± 10 percent of design conditions shown on drawings.

F. TAB REPORT
1. The report shall include all test and balance data, as well as information on any discrepancy from specifications or performance standards. All discrepancies shall be included in a separate section. As a minimum, the following items shall be included:
   a. Belt and drive sheave information (as installed and as changed), fan nameplate information, motor nameplate information, and amperage and voltage to all motors (in various operating modes where applicable). Also, maximum and minimum RPM settings on VFD units.
   b. Static pressure drops across all components of the air systems. Static pressure profile for each AHU system.
   c. Required and final balanced CFM at each system terminal unit. Include the terminal size, inlet static pressure, temperature, and velocities read to attain the required CFM.
   d. Pump and motor nameplate information, amperage and voltage to all motors, flow and pressure drop across all system terminals, pressure rise across the pump in psi and feet of head, both operating and shut-off, and maximum operating GPM.
   e. Refrigerant system operating amperages, pressures, and temperatures.
   f. Overload protection data for all motors shall be recorded. Starter and/or VFD brand, model, enclosure type, installed overload devices, original ratings and set points (and revised device ratings and set points when applicable) shall be recorded. If the starters (and/or VFDs) were furnished by the mechanical contractor, the overloads shall be verified and changed to the correct size when necessary, and so noted in the report. If the starters were furnished by the electrical contractor, the correct overload device sizes and settings shall be noted in the report and the electrical contractor shall be advised of all discrepancies.

2. A reduced set of drawings (11” x 17”) shall be included in the report with all terminals (VAV boxes, air outlets, inlets, coils, unit heaters, finned tube loops, radiant panel loops, etc.) clearly marked, all equipment designated, and all referenced to the device test reports. The contract drawings may be reduced and used for this purpose if they remain legible. Otherwise, CAD reduced-size drawings shall be obtained from the engineer.
3. The TAB contractor shall submit bound copies of the final TAB report to the owner or his/her representative at least 15 days prior to the mechanical contractor’s request for final inspection. The report shall include all operating data as previously listed, a list of all equipment used in TAB work, and shall be signed by the supervising professional engineer or certified TAB supervisor and certified TAB technician and affixed with his certification seal. Final acceptance of this project will not take place until a satisfactory report is received.

G. FIELD VERIFICATION
1. Upon request of the owner or engineer, a representative of the balancing firm performing the work shall demonstrate fluid flow quantities shown in the report by reading back outlets or terminals selected at random. It is understood that the operating mode of the system shall be the same for the read back as it was during balancing, and the number of readings verified will not exceed 10 percent of the total in the report.
2. When deemed necessary by the owner or engineer, the balancing firm shall run temperature, pressure, and/or humidity recordings, and shall be prepared to verify any of the report test results in the presence of the owner and/or engineer when requested.

END OF SECTION

SECTION 23 05 95

DEMONSTRATIONS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Demonstration of operation systems provided under Division 21, 22 and 23.

A. SEQUENCING/SCHEDULING
   1. Conduct demonstrations only after systems have been though start-up procedures, systems are complete and operating, test and balance is complete, and operating and maintenance data are complete.
   2. Demonstrations shall not be included as part of equipment start-up.

B. DEMONSTRATIONS
   1. Instruct the Owner's representative once, in presence of the Architect and Engineer, on the proper operation and maintenance of the mechanical systems. Include seasonal concerns and operations.
   2. Manufacturer's representative shall have a thorough understanding of each particular equipment. The manufacturer's representative for the following equipment shall be present to provide demonstrations: Boilers, Air- or Water-Cooled Water Chiller, Rooftop Units, Air Handling Units, Make-up Air Units, and Automatic Temperature Control Systems.

C. SUBMITTALS:
   1. Instruction Program:
      a. Submit two copies of outline of instructional program for demonstration and training, including a schedule of proposed dates, times, length of instruction time, and instructor' names for each training module. Include learning objective and outline for each training module.
   2. Demonstration and Training DVDs:
      a. Submit two copies within seven days of end of each training module.
      b. On each copy, provide an applied label with the following information:
         1. Name of Project.
         2. Name and address of photographer.
         3. Name of Architect.
         4. Name of Contractor.
         5. Date of recording.

B. COORDINATION:
   1. Coordinate instruction schedule with Owner's operations. Adjust schedule as required to minimize disrupting Owner's operations.
   2. Coordinate instructors, including providing notification of dates, times, length of instruction time, and course content.
   3. Coordinate content of training modules with content of approved emergency, operation, and maintenance modules. Do not submit instruction program until operation and maintenance data has been reviewed and approved by Architect and Engineer.

PART 2 – PRODUCTS

A. PROGRAM STRUCTURE:

1. Develop an instruction program that includes individual training modules for each system and equipment not part of a system, as required by individual Specification Sections, and as follows:
    a. Boiler(s) and boiler systems including boilers, pumps, and hydronic accessories (minimum 2 hours).
    b. Package rooftop units (minimum 2 hours)
    c. Make-up air systems including kitchen make-up air systems (minimum 2 hours)
    d. Package, custom, and large air handling units (minimum 2 hours)
    e. Domestic water heating systems including water heater, circulation pump(s), storage tanks, controls, and accessories (minimum 2 hours)
    f. HVAC instrumentation and controls; building automation systems (minimum 8 hours).

B. TRAINING MODULES:
    1. The operating and maintenance manual shall constitute the textbook for instruction.
    2. Review contents of manual in detail to explain all aspects of operations and maintenance.
    3. Develop a learning objective and teaching outline for each module. Include a description of specific skills and knowledge that participant is expected to master. For each module, include instruction for the following:
        a. Basis of System Design, Operational Requirements, and Criteria Include the following:
            1. System, subsystem, and equipment descriptions.
            2. Performance and design criteria if Contractor are delegated design responsibility.
            3. Operating standards
            4. Regulatory requirements
            5. Equipment function
            6. Operating characteristics
            7. Limiting conditions
            8. Performance curves.
        b. Documentation: Review the following items in detail:
            1. Emergency manuals
            2. Operations manuals
            3. Maintenance manuals
            4. Project record documents
            5. Identification systems
            6. Warranties and bonds
            7. Maintenance service agreements and similar continuing commitments.
        c. Emergencies: Include the following as applicable:
            1. Instruction on meaning of warnings, trouble indications, and error messages.
            2. Instructions on stopping.
            3. Shutdown instructions for each type of emergency.
            4. Operating instructions for conditions outside of normal operating limits.
            5. Special operating instructions and procedures.
        d. Operations: Include the following, as applicable:
            1. Startup procedures.
            2. Routine and normal operating instructions.
            3. Regulation and control procedures.
            4. Control sequences.
            5. Safety procedures.
            6. Instructions on stopping.
            7. Normal shutdown instructions.
            8. Operating procedures for emergencies.
            9. Operating procedures for system, sub-system, or equipment failure.
            10. Seasonal and weekend operating instructions.

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11. Special operating instructions and procedures.

e. Adjustments: Include the following:
    1. Alignments
    2. Checking adjustments
    3. Noise and vibration adjustments
    4. Economy and efficiency adjustments.

f. Troubleshooting: Include the following:
    1. Diagnostic instructions
    2. Test and inspection procedures.

g. Maintenance: Include the following
    1. Inspection procedures
    2. Types of cleaning agents to be used and methods of cleaning.
    3. List of cleaning agents and methods of cleaning detrimental to product
    4. Procedures for routine cleaning
    5. Procedures for preventative maintenance
    6. Instruction on use of special tools.

h. Repairs: Include the following:
    1. Diagnosis instructions
    2. Repair instructions
    3. Disassembly; component removal, repair, and replacement; and reassembly instructions.
    4. Instructions for identifying parts and components.
    5. Review of spare parts needed for operation and maintenance.

PART 3 – EXECUTION

A. PREPARATION
    1. Assemble educational materials necessary for instruction, including documentation and training module. Assemble training modules into a combined training manual.

B. INSTRUCTION:
    1. Facilitator:
        a. Engage a qualified facilitator to prepare instruction program and training modules, to coordinate instructors, and to coordinate between Contractor and Owner for number of participants, instruction times, and locations.

C. DEMONSTRATION AND TRAINING DVDS:
    1. General:
        a. Engage a qualified photographer to record demonstration and training DVDs. Record each training module separately. Include classroom instructions and demonstrations, board diagrams, and other visual aids, but not student practice. At the beginning of each training module, record each chart containing learning objective and lesson outline.

END OF SECTION

SECTION 23 05 97

SYSTEMS STARTING

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Start-up of operating systems provided under Divisions 21, 22 and 23.

B. START-UP AND TESTING
   1. Manufacturer's Representative: Present for starting of following systems:
      a. Boilers
      b. Rooftop Units
      c. Condensing Units
      d. Domestic Water Heater
      e. Chillers
      f. Air Handling Units (not including fan coil units, cabinet unit heaters, exhaust fans, and similar unitary equipment)
      g. Major equipment as required by District during design for specific locations such as make-up air units, energy recovery units, etc.
   2. Ensure that control systems are fully operational in automatic mode.
   3. On verification of the installation the manufacturer's representative shall report in writing to the Architect/Engineer. Report shall include any installation errors, or other fault in the system that would affect the performance of the system.
   4. Notify Architect at least five (5) days in advance of the start-up of mechanical systems.
   5. Conduct start-up and start-up testing in presence of Architect and Engineer. See applicable sections of Divisions 21, 22 and 23 for specific requirements.
   6. Complete tests required by code authorities including smoke detection, fire protection and health codes.
   7. Ensure that control systems are full operational in automatic mode.
   8. Boilers and Gas Fired Water Heaters – Supervision, Testing and Adjusting: Boilers representative shall provide a factory trained and factory authorized service personnel to perform the following:
      a. Start-up equipment and check out.
      b. Adjust firing and performance test. Testing and report shall be ASME short from for low and full load conditions. The equipment and instruments required to perform the tests must meet the approval of Owner.
      c. Burner shall be adjusted to not less than 9 to 2-1/2% Co2 at 0% CO (CO shall not exceed 200 PPM) and 4.5% O2 on gas firing. Flue gas analysis shall be made with approve type testing instruments. Flue temperature shall not exceed 450°F.
      d. The date of the above test and name of firm or individual making this test (Note: The Owner shall be notified 3 or 4 days prior to test) shall be submitted in triplicate, together with test report submitted in triplicate to the Owner. Tests to be run at a mutually accepted date when weather is such as to provide a heading load sufficient to sustain high fire operation. The test shall include but not be limited to the gas burner manifold in inches W.C., meter pressure at outlet CFH-gas, input MBH, stack temperature at flue outlet, CO2%, O2%, CO% and combustion efficiency %.
      e. Above combustion test shall be witnessed and certified by a Colorado State Registered Mechanical Engineer hired by the Contractor.
   9. Chiller and Rooftop Units: Chiller and rooftop unit manufacturer shall provide start-up and testing.
      a. Submittals

1. Engineer's approval is required for all Start-up/ Field Tests (SU/FT) reports which will be used by the manufacturer's representative for each item of equipment to be started. This report is to be included with the respective equipment submittals.

b. Field Tests and Start-up Coordination:
   1. Prior to the SU/FT services being performed, the Contractor shall verify that the systems have been installed properly and all utility services (water, electrical, gas, etc.) have been connected and are operational for all equipment.
   2. Contractor shall notify the Engineer and manufacturer's Representative seven (7) days before the SU/FT services are to be conducted. Contractor shall also coordinate with electric, control, mechanical and/or sheet metal contractors such that a qualified representative from each trade is available during SU/FT period.

c. Start-up and Field Tests:
   1. Completed start-up reports showing all field tests performed to prove compliance with the specified performance criteria shall be submitted to the engineer of record, upon completion and testing of the system.
   2. The following information, as a minimum, shall be included in the SU/FT reports, along with any additional testing procedures required and/or recommended by the manufacturer.
      i. Job Information Sheet
      ii. Job Location and address
      iii. Company name, contact, the installing contractor, engineer, and manufacturer's representative(s).
      iv. Manufacturers Unit Nameplate Data & Jobsite Tagging
      v. Pre-Start checklist procedure, to include but not limited to, the following items:
      vi. Confirm all fans operating and rotating correctly.
      vii. Refrigerant piping
      viii. All set points and setting for field adjustment of controls, control boards, safeties.
      ix. Check all field-installed electrical connections for accuracy.
      x. Inspect all control panel components, tighten any loose connections.
      xi. Check compressor crankcase oil levels.
      xii. Check the supply and exhaust fans for proper belt tension and sufficient lubrication. If necessary, readjust belt tension and lubrication fans.
      xiii. Check supply and exhaust fans optional spring isolators for proper adjustment.
      xiv. Check that power supply balance is within manufacturers recommended guidelines.
      xv. Remove all shipping blocks and brackets from unit.

d. Test/Start-up Log – Taken at 3 intervals, 30 minutes apart:
   1. Fans (supply, Condenser, Exhaust): Amp draw.
   2. Compressors: Voltage at compressor terminals, Voltage imbalance, Amp draw, % load.
   3. Refrigerant & HVAC Operating Conditions: Ambient temperature, evaporator entering and discharge temperature (DB&WB) on DX system, discharge and suction pressures, liquid and suction line temperatures, superheat, sub cooling, sight glass condition, % load.
   4. Safeties: List type and settings.

10. After test runs have been completed and systems have been demonstrated to be satisfactory and ready for permanent operation, clean permanent pipeline strainers and filters, replace air filters, properly adjust valve, and pump packing's, adjust belt tensions, secure drive guards in place, check lubrication and replenish if required.
11. If systems are not to continue in use following the start-up procedures, take steps to insure against accidental operation or operation by unauthorized personnel.

C. RESTRICTIONS/CRITICAL CRITERIA
1. Inspection: Inspect preceding work to ensure that:
    a. Electrical:
        1. Temporary services are disconnected, and permanent utility services are capable of full load.
        2. Connections in main switchgear and subpanels are tight.
        3. Necessary tests and check meter readings have been made.
        4. Wiring to motors and controls required for operational smoke and fire protection code demonstrations are complete.
    b. Mechanical:
        1. Specified tests on piping, ductwork and related systems have been made.
        2. Operational and performance tests have been made.
        3. Each piece of equipment comprising a part of the system has been checked for proper lubrication, drive rotation, belt tension, proper control sequence, and other conditions which may cause damage to equipment or endanger personnel.

END OF SECTION

SECTION 23 07 00

MECHANICAL INSULATION

PART 1 – GENERAL

A. SUMMARY – SECTIONS INCLUDED
   1. Piping Insulation including Valves and Fittings
   2. Equipment Insulation
   3. Duct Insulation

B. REFERENCED STANDARDS
   1. Requirements of Regulatory Agencies:
      a. Fire hazard classification: Insulation shall have a composite (insulation, jacket or facing, and adhesive to secure jacket or facing) fire hazard rating as tested by ASTM E-84, NFPA 225, or UL 723 not to exceed 25 flame spread and 50 smoke developed. Materials labeled accordingly.
      b. Energy conservation: Insulation and thickness shall be in accordance with requirements set forth in the International Energy Conservation Standard Code (IECC). In the event of a conflict between the thicknesses listed in this document and the IECC the most stringent requirements shall apply.

C. SUBMITTALS
   1. Product data: Submit for insulation, adhesive materials, and installation instructions.

D. CRITICAL CRITERIA/RESTRICTIONS
   1. Installation of Pipe Insulation
      a. Seal vapor barriers and run continuous throughout the following insulation systems: heating water, chilled water, and refrigerant piping.
      b. Insulate fittings and valves. Do not insulate hot water heating pipe within radiation enclosures, unions, flanges, strainers, flexible connections, and expansion joints. Terminate insulation neatly with insulating and finish cement trowelled on bevel.
      c. Finish insulation neatly at hangers, supports and other protrusions. Locate insulation over cover seams in least visible locations.
      d. Provide thermal hanger shields with galvanized metal saddles in the following locations:
         1. For piping fitted with VB jacket, at all hangers.
         2. For piping fitted without VB jacket, at all hangers carrying piping 1¼” and larger. For smaller pipe, insulation may be applied over hanger.
         3. For piping resting on trapeze hangers.
      e. Exposed locations: When pipe insulation is exposed with-in a finished room, provide a 22-gauge sheet metal cover. Sheet metal cover shall extend from floor slab to ceiling. When room does not have a ceiling the sheet metal cover shall terminate 12 feet above floor slab. Sheet metal cover not required in mechanical equipment rooms.
      f. Exterior: Cover with specified aluminum jacket secured with aluminum bands 12” on center. Seal joints with waterproof plastic cement.
   2. Installation of Equipment Insulation
      a. Low Temperature, 450°F to -20°F: Glass fiber insulation board or wrap: cut or mitered to fit the shape of the equipment. Secure with ½” x 0.020” galvanized steel bands or 16-gauge galvanized wire 12” on center. Weld pins or stick clips with washer may be used for flat surfaces. Space 18” apart. Stagger joints where possible and fill voids with vapor barrier mastic. Finish with eight (8) ounce canvas and fire-retardant vapor barrier mastic. Irregular surfaces may be insulated with insulating cement and finish in the same manner.

3. Installation of Duct Liner
    a. Duct Liner: minimum lining thickness per duct liner schedule. All duct liner shall be Type 2, except: Low pressure ductwork downstream of duct coils, acoustic elbows which shall be Type 1. Flame spread 25, smoke developed 50 per NFPA 90A. Install duct liner in accordance with referenced SMACNA standards for duct with maximum velocity of 4,000 FPM. Provide metal nosing at leading edges of all ductwork. Adhesively secured fasteners not allowed. Except as noted below, all rectangular supply return air and transfer air duct work shall be internally lined.
4. Installation of External Duct Insulation
    a. Concealed Locations
        1. Round Duct: Insulate with 1 PCF duct wrap.
        2. Rectangular Duct Insulate with 3 PCF external duct insulation.
    b. Exposed Locations Rectangular Duct: Insulation shall be fastened to duct with mechanical fasteners.
    c. Insulate round sheet metal ductwork. Omit external duct wrap for exposed supply air duct in Gymnasium.
    d. OA intake systems: Insulate plenums and ductwork with glass fiber external duct insulation.
5. Pipe insulation Schedule.
        a. Thicknesses: Insulate the following pipe systems with thickness indicated.

INSULATION THICKNESS IN INCHES FOR PIPE SIZES

Fluid Type and Operating Temperature Range	Insulation Conductivity		Nominal Pipe or Tube Size (Inches)				
	Conductivity Btu · in/(h · ft² · °F	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≤8
LPS/LPC (251 – 350)	0.29 – 0.32	200	3.0	4.0	4.5	4.5	4.5
LPC/LPC (201 – 250)	0.27 – 0.30	150	2.5	2.5	2.5	3.0	3.0
HS/HR (141 – 200)	0.25 – 0.29	125	1.5	1.5	2.0	2.0	2.0
HS/HR (105 – 140)	0.21 – 0.28	100	1.0	1.0	1.5	1.5	1.5
CHS/CHR (40 – 60)	0.21 – 0.27	75	1.0	1.0	1.0	1.0	1.0
CHS/CHR (< 40)	0.20 – 0.26	50	1.0	1.0	1.0	1.0	1.5

    b. Chilled water: Insulate complete as follows:
        a. Above grade: Insulate complete with fiberglass insulation.
        b. Below grade: Insulate complete with rigid closed cell pipe insulation. Adjust thickness to match performance of fiberglass pipe insulation.
        c. Exterior: Insulation with rigid closed cell pipe insulation. Insulation shall be nominal 2½” thick.
    c. Heating water: Insulate complete with fiberglass insulation, except interconnected radiation piping in the wall.
    d. LP steam and condensate: Insulate complete with fiberglass insulation.

e. Refrigerant liquid and suction lines: Insulate complete with fiberglass insulation or flexible elastomeric cellular insulation.
f. Insulation of piping exposed to freezing with heat tracer.

a.

6. Duct Work Insulation Schedule

LINER AND DUCT WRAP THICKNESS FOR DUCT LOCATION

Duct System	**Indoors (exposed or concealed) where subject to ambient temperatures similar to room conditions >15°F difference between duct and plenum temperature.**	**Where subject to ambient temperatures similar to outdoor temperatures**
Supply and Return Air (Lined)	1-1/2" – 2" (R-6 minimum installed)	2-1/2" – 3" (R-12 minimum installed)
Supply and Return Air (Wrapped)	2" – 2-1/2" (R-6 minimum installed)	3" – 3-1/2" (R-12 minimum installed)
Fresh Air/Outside Air (Lined)	Not Allowed	Not Allowed
Fresh Air/Outside Air (Wrapped)	2" – 2-1/2" (R-6 minimum installed)	3" – 3-1/2" (R-12 minimum installed)
Exhaust Air	Not Required	Not Required
Special Exhaust Systems	Not Required unless dictated by system requirements	Not Required unless dictated by system requirements

7. Equipment Insulation Schedule

a. Chilled Water Pump: Pump shall be covered with minimum 2-inch foamed glass. Insulation shall be boxed around pump volute, bearings, and portion of pump below volute. Cover with mastic reinforced with white starch sized glass fabric and finish with white, brushed smooth mastic which conceals the fabric. Install to permit servicing.

PART 2 – PRODUCTS

A. ACCEPTABLE MANUFACTURERS
1. Mineral Fiber (Glass Fiber) Insulation:
   a. Manville
   b. Certainteed Manson
   c. Ownes Corning
   d. Knauf
2. Pipe Insulated Fitting Covers:
   a. Manville
   b. Cerainteed Manson
   c. Owens Corning
   d. Ceel-Co
3. Flexible Closed Cell Elastomeric Insulation:
   a. IMCOA Pipe Insulation
   b. Armstrong World Industries
   c. Armaflex

d. Armacell
4. Fire Retardant Vapor Barrier Mastic: Benjamin Foster
5. Insulate and Finishing Cement:
   a. Schuller International, Inc.
   b. Lamtec
   c. Alpha Associates
   d. Approved Substitute
6. Duct Liner:
   a. Johns Manville
   b. Certainteed
   c. Knauf
   d. Owens Corning
7. Rigid Closed Cell Insulation:
   a. Pittsburgh Corning Foamed Glass
   b. Owens Corning
   c. Certainteed
   d. Knauff
   e. Approved Substitute
8. Mastic Used In Conjunction With Rigid Closed Cell Insulation:
   a. Pittsburgh Corning Pittwrap or Pittwrap SS II
   b. Compatible with insulation system
   c. Approved Substitute

B. MATERIALS
1. Pipe Insulation
   a. Above grade, interior, -20°F to +450°F: Glass fiber pipe insulation ASTM C 547 Type 1. Maximum k/inch: 0.25 at 75°F. All service jacket with self-sealing laps.
   b. Above grade, interior: -40°F to +210°F: Flexible closed cell elastomeric insulation ASTM C 534 Type 1 and ASTM D 1056. Maximum k/inch: 0.28 at 75°F. Butt seal joints with contact adhesive.
   c. Above grade, exterior: Same as interior except cover with 0.016 smooth aluminum jacket. Seal all joints and seams with silicon sealant.
   d. Below grade, 2” and under, -40°F to +210°F: Flexible closed cell elastomeric insulation. ASTM C 534 Type 1 and ASTM D 1056. Maximum k/inch: 0.28 at 75°F. Butt seal joints with contact adhesive.
   e. Below grade, over 2”: Non-flammable waterproof mineral powder.
   f. Below Grade: 170°F and below Rigid Closed cell ASTM C 552 with Pittwrap jacked. Maximum k/inch: 0.35 at 75°F. Average density 8.5 LBS per cubic foot. Compressive strength 100 PSI.
2. Fittings and Valves Insulation:
   a. For glass fiber insulation: Pre-molded 30 mil PVC cover with fiberglass inserts. Seal at end and throat on cold systems.
3. Vapor Barrier Mastic Coatings: Perm rating not more than 0.25 when tested in accordance with ASTM E 96, Procedure a Fire Retardant.
4. Adhesives, Sealers, Facings, and Vapor Barrier Coatings: Compatible with materials to which applied, and shall not corrode, soften, or otherwise attack the pipe or insulation materials in either the wet or dry state. Use only adhesives, sealers, facings, and vapor barrier coating recommended by the approved manufactures and insulation materials.
5. Chemical for Treating Paper: Non- Soluble.
6. Equipment Insulation:
   a. Equipment Insulation, -20°F to 450°F.

b. Glass Fiber Insulation Board, ASTM C 612, Class 2. Maximum k/inch: 0.23 at 75°F. Density: 6 lbs./cu.ft. Foil-scrim-kraft-facing.
c. Foamed Glass Insulation Board, ASTM C 552. Maximum k/inch: 0.35 at 75°F. Average density 8.5 lbs. per cubic foot. Compressive strength 100 PSI.

7. Ductwork Insulation
   a. Type 1 duct liner insulation shall be black coated surface resilient glass fiber with non-combustible coating. Liner shall have a k factor of 0.25 or less at 75°F mean temperature. Noise reduction coefficient shall not be less than 0.70 for 1" thickness and 1.00 for 2" thickness, based upon type "A" mounting. All fasteners shall be welded type.
   b. Type 2 duct liner insulation shall be black coated surface resilient glass fiber with non-combustible coating. Liner shall have k factor of 0.24 or less at 75°F mean temperature. Noise reduction coefficient shall not be less than 0.70 for 1" thickness based upon ASTM C 423-81 and ASTM E 795 type "A" mounting. All fasteners shall be welded type.
   c. Exterior of duct- wrap: Glass fiber blanket duct wrap, ASTM C 553 Type 1, Class B3. Maximum k/inch: 0.23 at 75°F. Three-pound (3 lbs.) density. Foil-scrim-kraft facing.
   d. Exterior of duct – wrap: Glass fiber blanket duct wrap, ASTM C 553, Type 1, Class B3. Maximum k/inch: 0.26 at 75°F. One pound (1 lb.) density. Foil-scrim kraft facing.

END OF SECTION

SECTION 23 08 10

VARIABLE FREQUENCY DRIVES

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Variable Frequency Drives to be furnished by Mechanical Contractor and installed by Electrical Contractor. The data listed below are the minimum VFD requirements.

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. ANSI/NFPA 70 – National Electrical Code
   2. UL 508 – UL Standard for Safety Industrial Control Equipment
   3. UL 508C – UL Standard for Safety Power Conversion Equipment
   4. NEMA ICS 7.1

C. SUBMITTALS
   1. Shop Drawings and Product Data:
   2. Variable Frequency Drives
      a. Operating and Maintenance Data:
      b. Variable Frequency Drives

D. RESTRICTIONS/ CRITICAL CRITERIA
   1. Adjustable frequency NEMA 1 drive package shall consist of circuit breaker disconnect, line reactor, EMI/RFI filter, 2 contactor bypass, 120 V control transformer, control circuit terminal for digital and analog field wiring. AC Line fuses do not meet specification.
   2. Drive door shall have mounted and wired, Hand-Off-Auto Switch, Manual Speed Potentiometer and AFC-Off-Bypass Switch. Manual speed bypass shall not be electronic type integrated into VFD panel.
   3. Entire drive package shall be UL508C listed as coordinated with NEMA ICS 7.1. Refer Section 23 00 04 for motors.
   4. Enclosure and heat sink fans shall be accessible from the front and not require the removal of the AC drive power converter for fan replacement.
   5. Speed range shall be from a minimum of 1.0 Hz to a maximum of 720 Hz.
   6. Environmental Ratings: AC drive shall be designed to operate in an ambient temperature from -10° C to 40° C. AC Drives and Type 3R enclosure shall be designed to operate -10° C to 50° C and in full sunlight. Maximum relative humidity shall be 95%, non- condensing. The AC Drive shall be derated per drive manufactures specifications for altitudes about 3,300 feet.
   7. Ratings: The AC Drive shall operate from an input frequency range of 60 Hz (+) 5%. The efficiency of the AC Drive at 100% speed and load shall not be less than 97%. The displacement power factor shall not be less than 0.98 lagging under any load or speed condition.
   8. Protection: Upon power up, the AC Drive shall automatically test for valid operation of memory, loss of analog reference input, loss of communication, power supply, control power and pre-charge circuit. Short circuit coordination per UL 508C and NEMA ICS 7.1. Programmable ride-through function to allow logic to maintain control for a minimum of one-second (60 cycles). For fault conditions other than ground fault, short, circuit, internal fault or short circuit, an auto restart function will provide up to 6 programed restarts. Time delay between restarts shall be 60 seconds. Drive to have UL 508C listed overload protection and meet IEC 60947.

9. Adjustments: AC Drive to be factory programed to operate all specified optional devices. Acceleration and deceleration ramp to be adjustable from 0.05 to 999.9 seconds. Maintain constant volts/Hz ratio during acceleration.
10. Keypad display interface.
11. Operator Controls: 24V dc control power. Combination enclosure with dedicated operator controls. H-O-A, Manual Speed Potentiometer, AFC-Off Bypass switch.
    a. Bypass shall be manual type bypass, electronic bypass not acceptable.
12. Harmonic Mitigation: AC Drive shall include a line reactor mounted inside the drive enclosure to reduce power system harmonics and provide quality power system harmonics and power quality protection for the drive.

E. Coordinate temperature control requirements with controls 23 09 00 for interface with building automation system.
F. Demonstration: Instruct the Owner's personnel in accordance with Section 23 05 95. Factory trained service technician to supervise start-up each variable frequency drive.

PART 2 – PRODCUTS

A. VARIABLE FREQUENCY DRIVES
    1. Acceptable Manufactures:
        a. ABB
        b. Danfos
        c. Graham
        d. Magnetek
        e. Mitsubishi (District preferred)
        f. Reliance
        g. Square D
        h. Yaskawa

END OF SECTION

SECTION 23 09 00

BUILDING MANAGEMENT AND AUTOMATIC TEMPERATURE CONTROL SYSTEMS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. The building Management and Automatic Temperature Control System shall be complete in all respects, including equipment, labor, materials, and services.
   2. The General Provisions of the Contract, including the General Conditions of Supplementary General Conditions, apply to the work specified in this Section.
   3. Certification: At the completion of the project, the Control Contractor shall verify in writing that the control system has been fully exercised through every mode of operation and that the installed system performs exactly as specified in the sequence of operation. The Engineer will not conduct a final inspection of this project until receipt of this certification. Certification shall include as a minimum, a printout of all points of control with set point values and current operating status.

B. BID REQUIREMENTS
   1. The Temperature Control shall be bid to the Owner and assigned to the Mechanical Contractor.

C. SUBMITTALS
   1. Product Data:
      a. Shop Drawings: Show wiring diagrams, auto valve schedule, piping diagrams for all equipment arrangement in panel fronts, bill of materials for all devices, written descriptions of sequence, temperature control diagram, and control valve schedule.
      b. Product Data: Include for all devices; show terminal/ port labels, internal switching, etc., as required to enable complete understanding of the function of the device.
   2. Operating and Maintenance Data:
      a. BMS/ATC systems

D. RESTRICTIONS/ CRITICAL CRITERIA
   1. All electrical work performed in the installation of the BAS/ATC system as described in this specification shall be per the National Electrical Code (NEC) and per applicable start and local codes. Where exposed, conduit shall be parallel to building lines properly supported and sized at a maximum of 40% fill. In no cases shall field installed conduit smaller than ½" trade size be allowed. Where conductors are concealed (tenant spaces), cable rated for use in return air plenums shall be used.
   2. Acceptance Procedure: Upon completion of the calibration, contractor shall startup the system and perform all necessary testing and run diagnostic tests to ensure proper operation. Contractor shall be responsible for generating all software and entering all database necessary to perform the sequence of control and specified software routines. An acceptance test in the presence of the Owner's Representative or Engineer shall be performed. Final acceptance and project completion shall not be considered until verification of control work is demonstrated to District controls manager. Demonstration shall include verification of specific equipment application and sequence, delivery of as-build control diagrams, sequences of operation, and equipment O&M's. Punch list items as identified by the District and Consulting engineer shall be marked as complete and verified prior to acceptance.
   3. Sequence of Controls
   4. Sequence of Controls to be determined by Consulting Engineer.
   5. All controls components shall be specified to be provided by the temperature controls contractor and factory installed. Include specific installation requirements in individual

specification sections as applicable. Packaged unit controls are not acceptable unless approved by the District Project Manager and District Controls Specialist. BACNET controllers shall be limited to those approved by the District.

E. DEMONSTRATION AND TRAINING:
   1. The Contractor shall provide a minimum of 16 hours of training in 4-hour blocks one day per week on system operations and provide control demonstration time at the job site for the Owner's personnel.
   2. This Contractor shall provide at least 4 hours in one session of classroom training at times and location as directed by the Owner. The training shall focus on design, operation, and maintenance procedures of the products installed and shall cover:
      a. Hardware configuration, including PC boards, switches, communication and point wiring, and location of all sensors and control devices.
      b. Hardware maintenance, calibration, troubleshooting, diagnostics, and repair instructions.
      c. Operation of central workstation, including logging on and off, interrogating the system, producing reports, acknowledging alarms, overriding computer control, changing firmware and software parameters, and generating and linking graphic screens.
      d. The operational sequence of each system, including normal and abnormal operating modes, operating control strategies, and operator actions required to reset or monitor the system.
      e. Programming using the editor, program design, syntax, and loading of custom control software.
      f. Recovery procedures from power failures.
      g. Alarm formats.
      h. Maintaining software and programming backups.
   3. The instructor(s) for the above sessions shall be employee(s) of the Control Contractor whose primary function is customer training and applications support.
   4. A minimum of two copies of the most current control drawings shall be provided to the District before the training begins. These shall be in addition to the drawings to be provided under Part 1 Shop Drawing requirements, if the O&M Manuals have not been turned in to the Architect before the time of the training.
   5. The training may be phased. The Owner may elect to conduct training and demonstration in two- to four-hour sessions over the life of the warranty period. All instructional material shall be available to each employee at each training session up to a maximum of ten (10) individuals.
   6. All demonstration and training sessions shall be coordinated with the CCSD Controls Application Engineer.

PART 2 – PRODUCTS AND SYSTEMS

A. MANUFACTURERS
   1. The specified systems are based on a Delta system by Setpoint Systems Corporation. Alternate listed manufacture may submit a bid based on this specification as the minimum standards. Alternate manufacturer’s operator interface, software, reporting capabilities, sequence of operation and points list shall be equal to or in excess of this specification.

B. GENERAL
   1. The Building Automation System shall include but not be limited to the following components.
      a. The Operator interface shall consist of hardware and software that allows full user monitoring and adjustment of system parameters.

b. System Application Controllers shall manage the Energy and Building Management capabilities of the automation system as well as facilitate remote communications and central monitoring.
c. Application Specific Controllers shall provide distributed, pre-engineered control, specific to the mechanical equipment specified.
d. Custom Application Controllers with distributed, custom programming capability shall provide control for nonstandard control sequences.
e. The Data Communications capability shall allow data to be shared between the carious controllers in the architecture.
f. The system software shall include system software for global application functions, application software for distributed controllers, and operator interface software.
g. End devices such as sensors, actuators, dampers, and relays.

2. The failure of any single component shall not interrupt the control strategies of other operational devices. System expansion shall be through the addition of end devise, controllers and other devices described in this specification.
3. The contractor will provide factory software upgrades to the Owner at no charge, for a period of 5 years after system acceptance.

C. OPERATOR INTERFACE
1. An interface shall be provided to allow the building operator to view and acknowledge alarms, access/edit system database information, view system displays and reports, and customize the system as described in this specification. The contractor shall provide any software and hardware required to accomplish the operator interface as specified at the school.

D. SYSTEM APPLICATION CONTROLLERS
1. The Building Automation System shall be composed of one or more independent, stand-alone, microprocessor-based System Application Controllers to manage the global strategies described in application software section.
2. The controller shall continually check the status of all processor and memory circuits. If a failure is detected, the controller shall:
a. Assume a predetermined failure mode.
b. Emit an alarm.
c. Display card failure identification.

E. APPLICATION SPECIFIC CONTROLLERS
1. Application Specific Controllers shall be stand-alone, microprocessor based Direct Digital Controllers with sufficient memory to manage its operating system, database and programming requirements.
2. The Application Specific Controller shall be pre-programmed, tested, and factory mounted on the mechanical equipment to ensure reliability. Where factory mounting is not possible, the controllers shall be factory programmed and tested prior to shipment on the job site. The controllers shall be clearly labeled as to controller type, where it is to be installed, and software address (if applicable). The controller shall be fully tested upon installation to ensure that it is properly matched to the equipment it is controlling.
3. The DDC Unitary, Application Specific, and Network Controller shall be configured such that the Portable Operatory Interface can be plugged directly into it or within sight for programming, editing and other operator functions.

F. INPUT/OUTPUT INTERFACE
1. Hardwired inputs and outputs may tie into the system through System Application, Custom Application, or Application Specific Controllers. Slave devices are also acceptable. Any

critical points requiring immediate reaction shall be tied directly into the controller hosting the control software algorithm for the critical function.

2. Binary inputs shall allow the monitoring of on/off signals from remote devices. The binary inputs shall provide a wetting current of 12MA at 12 VDC to be compatible with commonly available control devices. All status points shown on the point list shall be positive proof differential pressure or current sensing binary switches.
3. Analog inputs shall allow the monitoring of low voltage, current, or resistance signals and shall have a minimum resolution of 0.1% of the sensing range. Analog inputs shall be compatible with, and field configurable to commonly available sensing devices.
4. Binary outputs shall provide a continuous low voltage signal for on/off control of remote devices. Where specified in the sequence of operations or indicated on the points list, binary outputs shall have 3-position (on/off/auto) override switches, status lights and shall be selectable for either normally open or normally closed position.
5. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0 to 10 VDC or a 4 to 20 milliampere signal as required to provide proper control of the output device.
6. System architecture shall allow for point expansion in one of the following ways:
   a. The addition of input/output cards to an existing System Application Controller.
   b. The addition of unitary or application specific controller.
   c. 10% expansion capacity for all point types in all DDC panels.

G. TEMPERATURE SENSORS:
1. Temperature sensors shall be Resistance Temperature Detector (RTD) or Thermistor as dictated by the requirements of this specification.
2. Accuracies shall be +/- 1 degree F for standard application where high accuracy is required, accuracies shall be +/- 2 degrees F.

H. DIFFERENTIAL PRESSURE SWITCHES:
1. Differential Pressure Switches shall be furnished as indicted for status purposes in air and water applications. Provide single pole double throw switch with fully adjustable differential pressure settings.

I. CONTROL THERMOSTATS
1. High Limit Thermostats: High limit thermostats shall be manual reset type set at 120* F.
2. Low Limit Thermostats:
   a. Safety low limit thermostats shall be vapor pressure type with a 20-foot minimum element. Element shall respond to the lowest temperature sensed by any one-foot section.

J. CONTROL VALVES:
1. The automatic control valve shall be sized by the Controls Contractor for the appropriate pressure drop specified by the A/E to ensure proper throttling performance at all system loads.
2. Close off (differential) Pressure Rating: valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:
   a. Water Valves:
      1. Two-way: 150 percent of total system (pump or building domestic water pressure) head.
      2. Three-way: 300 percent of pressure differential between ports A and B at design flow or 100 percent of total system (pump) head.
3. Water Valves

a. Body and trim style and materials shall be per manufacturer's recommendations for design conditions and service shown, with equal percentage ports for modulating service, except where stated otherwise.
b. Sizing criteria
    1. Two-position service: line size.
    2. Two-way modulating service: pressure drop across the valve in a wide-open position, with full flow through the valve, shall be equal to 50 percent of the available pressure differential between the mains, with a minimum of four (4) psi.
    3. Three-way modulating service: pressure drop across the valve in a wide-open position, with full flow through the valve, shall be equal to twice the pressure drop through the heat exchanger (load), with a three (3) psi minimum.
c. Construction
    1. Valves ½" through 2" shall be bronze body or cast brass ANSI Class 250, spring loaded, Teflon or ring packing, and stainless-steel stems. Two-way valves to have replaceable composition disc.
    2. Characterized ball valves may be utilized in lieu of globe valves. Ball valves shall be bronze body or cast brass ANSI Class 250, with stainless steel or stainless steel coated bronze full port ball, and stainless-steel stems. Valve characterized for uniform modulation of valve through entire control range.
    3. 2-½" valves and larger shall be cast iron ANSI Class 125 with guided plug, stainless steel stems and Teflon or ring packing.
d. Water valves shall fail normally open or closed as scheduled on plans or as follows:
    1. HW zone valves - normally open.
    2. Heating coils in air handlers - normally open.
    3. Chilled water control valves - normally closed.
    4. Other applications - as scheduled or as required by sequence of operation.
e. Butterfly valves: modulating, three-way valves, or two-position valves 4" and larger may be tight closing butterfly valves. Full-lug type, 250 psi WOG, extended neck, cast iron body, aluminum/bronze disk, stainless steel shaft, field replaceable cartridge design, EPDM seat and seal with integral actuator. The modulating, three-way valve substitute shall consist of linked butterfly valves with a factory-installed linkage. Modulating valves shall be sized for three (3) psi pressure drop.
f. Evaporative cooler drain and fill valves
    1. Coordinate with evaporative cooler manufacture for additional requirements for the evaporative cooler package. Drain/fill valve assemblies may be specified with equipment in lieu of by temperature control contractor. TC shall control drain/fill assembly.
    2. Bronze, full-port, two-piece body design; chrome-plated, solid bronze ball with Teflon seats, stem packing shall be adjustable for wear with adjusting screw, 150 WSP, 600 WOG.
    3. Bronze valve material composition shall meet ASTM B62.
    4. Provide valve complete with actuator, mounting bracket, and all required linkage.
    5. Valve normal position shall be as shown on the drawings.
g. For systems with glycol solutions, provide documentation that the valve components in contact with the fluid are compatible with glycol.

K. AUTOMATIC DAMPERS
1. All dampers not specified with equipment in other sections of the specifications shall be furnished by the Temperature Control Contractor and shall be single or multiple blade type as required.
2. All damper frames are to be constructed of #13 Gauge G90 galvanized sheet metal, roll formed into channels and welded for maximum strength and shall have flanges for duct mounting.

3. All blades shall be fabricated from single #16-gauge G90 galvanized sheet metal. Blade pins shall be steel, zinc plated, and chromate treated to provide no-slip pivoting when a damper is used as a single module or is interconnected with others. Blades shall be suitable for high velocity performance.
4. Dampers used for outside, return, or exhaust air, and those used for zone mixing dampers shall be provided with seals to provide tight shut off along all edges of all blades; tight closing and low leakage damper of less than 4.5 cfm/ft. at 1" static pressure. Bearings shall be oil impregnated to provide constant lubrication.
5. Blade edge seals and top and bottom channel seals shall be easily replaced if they are damaged. An internal stop shall be provided on all dampers to prevent over-rotation in the closed position.

L. ACTUATORS:
1. Actuators shall be electronic, spring return, low voltage (24VAC) and properly selected for the valve body, damper frame and service.
2. Actuators shall be fully proportioning and be spring returns for normally open operation as called out in the sequence of operations.

M. OPERATOR INTERFACE SOFTWARE
1. System Security:
   a. User access shall be secured using individual security passwords for a minimum of eight users.
   b. User log-on/log-off attempts shall be recorded.
   c. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user definable.
2. Alarms:
   a. The building Automation System shall provide audio, visual, contact closure and remote telephone annunciation for:
      1. Remote equipment failure
      2. Equipment run time.
      3. Number of start/stops
      4. Program failure
      5. Card failure
      6. Sensor failure
   b. An after-hours alarm processing function shall transfer the alarm message to an alternate location equipped with a terminal device and an auto-answer modem. The telephone number and the time of day to start and stop after hours processing shall be user designated.
3. Dial-up Communications: An autodial-up and auto-answer communications utility shall allow stand-alone System Application Controllers to communicate with remote operator station over voice grade phone lines.

N. ENERGY MANAGEMENT SOFTWARE
1. The following Energy Management capabilities shall be furnished standard as part of the building Automation System.
   a. Demand limiting Capability: The demand limiting program shall monitor building power consumption from signals generated by a pulse generator at the building power meter or from a watts transducer or current transformer attached to the building feeder lines.
   b. The demand limiting program shall be self-adjusting and shall control minimum of two independent demand limiting applications.

c. Demand limiting parameter shall include 15- or 30-minute intervals, shed/restore dead band with as well as maximum off-time and temperature limits for each load to ensure that Indoor Air Quality and occupant comfort are not compromised.
d. The HVAC equipment shall be protected by the anti-recycle timer described above.
e. Input capability shall also be provided for an end-of-billing period indication.

O. BUILDING MANAGEMENT SOFTWARE
1. Genera: The following Building Management capabilities shall be furnished as part of the Building Automation System:
2. Time Override: A timed override program shall be provided to enable to building operator to set up devices or groups of devices to be temporarily turned on for a defined period based on binary inputs, analog inputs, or CRT inputs.
3. Direct Digital Control: The Direct Digital Control Program shall allow modulating control of remote devices based on sensed data.
4. Custom Programming Language: A custom control language capability shall be provided to allow the operator to create real time, equation based, custom control routines.
5. Run Time Maintenance: The system shall monitor equipment status and generate maintenance messages based upon user designated run time, starts and/ or calendar date limits.
6. Expanded Messages: The user shall be able to define a minimum of 99–180-character messages for automatic printing in the event of system alarm and/or run time and maintenance event.
7. Reports and Logs: The system shall include the capability to store, review and print the following reports and logs. In addition, if a PC interface is specified, these reports shall be saved to diskette as an ASCII file for use by other owner furnished software packages.
    a. Current Summary Report: An instantaneous summary of building status including heating and cooling degree days, on and off-peak electrical demand performance, current KWH consumption and summary for critical temperature sensors listing today’s minimum and maximum values.
    b. Monthly Summary Report: An end of the month summary of building status including heating and cooling degree days, on and off-peak electrical demand performance, current electrical KWH consumption and summary for critical temperature sensors listing this month’s minimum and maximum values.
    c. Monthly Demand Limiting Report: A report for logging the electrical demand performance (both on and off peak), and the KWH consumption for each of the two utility meter programs shall be provided to the building operator. Included shall be the times of todays and yesterday’s demand peaks as well as the time and date of the monthly demand peaks. This report shall of electrical performance for the present day and pervious 32 days.
    d. Yearly Demand Limiting Repot: A report for logging the electrical demand performance (both on and off peak) and KWH consumption for each of the two utility meter programs. This report shall log electrical performance for the present month and previous 12 months.
    e. Yearly Meter Report: A report for logging the electrical KWH consumption for up to 6 sub meters. This report shall log electrical performance for the present month and previous 12 months.
    f. Yearly Degree Day Report: A current month and previous 12-month summary of heating and cooling degree days.
    g. Weekly Temperature Report: A previous 7-day summary of the minimum and maximum temperatures for the critical zone temperature sensors.
    h. Weekly Override Time Report: A pervious 7-day summary of after-hours override usage (in hours and minutes) for the timed override groups.

i. Monthly Override Time Report: A current and previous month summary of after-hours override usage (in hours and minutes) for the timed override groups).
j. Trend Logs: A custom report generator allowing the user to trend and store at least 24 sample points based on a user-defined schedule.
k. Event Logs: The system shall track system events including alarms, log-ons and diagnostics.
l. Input/output Status Reports: This reporting tool shall allow the operator to review the status of all system points.
m. HVAC Equipment Reports: Reports shall be provided which indicate the HVAC equipment status as well as the status of all input/output points of connected HVAC equipment.

P. ANTI-RECYCLE TIMER PROTECTION
1. A software program shall be provided to allow each individual piece of HVAC equipment to be individually programmable with “minimum on” and “minimum off” timers to protect HVAC equipment from rapid cycling due to system or operator error.

Q. LOCAL CONTROL PANELS
1. NEMS-1 locking panels shall house DDC controllers’ transformers, power supplies, communications interfaces, transducers/sensors that do not need to be field mounted, relays, wire termination/junction strips, etc.
2. Devices shall be flush mounted on panel face.
3. Manual timer overrides are not permitted. Manual overrides will be managed through a software function. If any manual override exists, they shall be removed as part of this project.
4. Internal components shall be securely mounted on removable sub-panels. Each component shall be individually labeled with function and device identification, as shown on control/interlock shop drawings. Label all components in accordance with Division 26 Electrical Identification.
5. Interconnections between internal and face-mounted devices pre-wired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL-listed for 600-volt service, individually identified per control/interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
6. Provide on/off power switch with over-current protection and a 1-½” main air gauge for control pressure sources to each local panel. Provide a 120-volt duplex outlet inside each control panel that houses a DDC controller (except VAV controllers) if there is not an outlet within 5’ of the enclosure.
7. All control panel locks shall be the same. Contractor shall give the keys to the District Controls Application Engineer at completion of training.
8. All field devices shall be mounted in panels. Exceptions include devices with enclosed electrical terminations, and designed to be installed on the controlled/monitored equipment and (e.g., pipe/duct temperature/pressure sensors) or those for space mounting (e.g., space temperature sensors)

PART 3 – EXECUTION

A. CONTROL WIRING
1. Provide all control and communication wiring (except CAT 6 for Ethernet/IP) including that for connecting equipment controls and Subsystems to the DDC System.
2. The Cat 6 wiring drops that interconnect the DDC System Controllers, equipment controls, and Subsystems, and the devices to the District Front End shall be installed by the telecom contractor.

3. Final wiring from the DDC System Controllers, equipment controls, and Subsystems to the drops shall be provided by the Controls Contractor.
4. Control wiring shall be concealed except in equipment rooms.
5. Electrical installation will be according to the following requirements:
    a. All wire and cable runs will be protected with metallic conduit or cable trays. Exceptions are as follows:
        1. NEC Class 2 low voltage wiring where not exposed to view such as above suspended ceilings, in shafts, etc., may be run in cable tray or properly secured to the building (when approved by code authority).
        2. Wiring enclosed in temperature control panels.
6. All wire and cable runs will be labeled or otherwise coded at both ends, the labeling or coding scheme should be well- organized, consistent, and documented (submitted).
7. All low voltage instrumentation wiring shall be minimum 18 AWG stranded copper for sensors and communication. All low voltage cables in ceilings shall be UL listed for air plenum service and suspended neatly from the overhead structure. Do not lay on top of ceiling tiles.
8. Flexible metal conduits and liquid-tight, flexible metal conduits shall not exceed 3' in length and shall be supported at each end. Flexible metal conduit less than ½" electrical trade size shall not be used.
9. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal conduits shall be used.
10. Low-voltage (24V or less) AC or DC wiring shall not be run in conduit containing 120 VAC wiring.
11. Label all temperature control wiring junction box covers with an adhesive backed water-proof flexible mylar label with the letter's T/C, using an orange background with black letters to differentiate them from junction boxes installed by the electrical and fire alarm contractor. The labels shall be 3" x 3''.
12. Use proper size wire nut type connectors on all sensor wiring with factory recommended twisting.
13. Crimp connectors are not allowed on sensor wiring.

B. INSTALLATION AND SETUP REQUIREMENTS
    1. Install discharge air temperature sensors in all VAV boxes with reheat coils. Wire each sensor to an AI point termination on the box's associated Zone Controller.
    2. Averaging Sensor Elements, Low-Temperature Detection Elements
        a. The elements of averaging sensors shall be long enough to serpentine across the area served. The element shall cover the duct area completely and shall be equally spaced. Use copper radius clips at the bends and protect sensor elements at duct penetrations and other points of contact with poly-tubing.
        b. Low-temperature detection devices shall fully cover the coil face as described in the Part 2 Controls requirements. Mount and protect elements as described above.
        c. Sensing elements shall be located so as not to interfere with filter changing or other maintenance activities. The elements shall be mounted downstream of the coil served.
    3. Averaging-type sensing elements shall be supported in ductwork or air-handling units using ½" EMT or other auxiliary support.
    4. For all applications utilizing outside air, relief, isolation, or exhaust dampers: install an E/P to automatically close the dampers when its associated air-handling unit or fan is turned off. The E/P shall be wired so the damper is closed when the fan or AHU is turned off with the starter switch in the OFF or AUTO position (or in either the BYPASS or VFD modes when a variable-frequency drive is used). The dampers shall open, or return to automatic control, as required, when the fan or AHU is turned on, whether the starter switch is in the HAND or AUTO position (or in either the BYPASS or VFD modes when a variable-frequency drive is used).

5. The name of each point shall conform to the District’s standard protocol. The intent is to utilize standard point names within a project and from one project to another. Consult District Controls Application Engineer for current standards.
6. Utilize programming protocol used by CSS whenever possible.

C. CONTROL DEVICE LOCATIONS
1. Outdoor temperature or RH sensors shall be located on the design drawings, and on a northern exposure, in a shaded location, preferably in a place where there is a continuous stream of outside air over the sensor, unless shown otherwise. Consult with the District Controls Application Engineer to determine the preferred locations.
2. Provide wind-dampening "weatherhead" with insect screen on outdoor atmospheric pressure-sensing point and mount at least 3' above the highest roof structure to minimize false readings due to wind direction and/or eddies.
3. Remote control devices not in local panels shall be accessible for adjustment and service, below 6’ above finished floor whenever possible.

D. CONTROL PANELS
1. Electro-pneumatic switches (EPs) and relays shall be grouped together and installed in a single, central panel located next to the enclosure housing the associated controller. At the Contractor's option, the relays and EPs may be installed in the same enclosure as the controller. Remote mounted relays and EPs are not acceptable. Remote-mounted PE switches are allowed.
2. Electrical power for each panel shall be from a dedicated circuit. Where available in a building, utilize emergency power circuits for all controls. It is the A/E’s responsibility to show a sufficient number of dedicated controls circuits in locations where control power will be needed on the electrical drawings. For retrofit applications, where connecting to existing control-power wiring, it is the Contractor's responsibility to verify that the power source is from a dedicated circuit. Note: Coordinate power sources with the Electrical Engineer, show all equipment requiring 120V power on the drawings.

E. IDENTIFICATION
1. All control equipment shall be clearly identified by control shop drawing designation code and a functional description as follows:
    a. Control valves: brass tags.
    b. Other remote-control devices and sensors (located both within and outside of control panels): metal tags, plastic laminate labels, or (on non-porous surfaces only) adhesive backed labels (i.e., from a laser printer or a dedicated label-making device). Do not attach tag or label to removable covers, adjacent surface etc.,
    c. Control panels: Engraved plastic laminate labels. Indicate panel number and systems served.
    d. All wiring, including wiring within factory-fabricated panels, shall be labeled within 2" of each termination with DDC point number/controller number or other descriptive information.
    e. Plenum-rated cabling shall use different jacket colors to differentiate between the following:
        1. Input point wiring.
        2. Output point wiring.
        3. Communications (i.e., MS/TP).
        4. Low Voltage power.
    f. All metal and plastic engraved labels shall be secured with chains, nylon tie-wraps, or rivets. Permanent adhesive is acceptable only when mechanical fasteners would damage the labeled equipment.

g. All switches, relays, and panel components shall be labeled. Relay bases shall be labeled, not the removable relay cube.
h. Labels shall not be mounted on removable surfaces, such as cable tray covers.

F. OPERATOR INTERFACE AND OTHER SYSTEM CONFIGURATION
1. General
a. All DDC System schedules, alarms and trends for this project shall be set up under this section.
b. Alarms and trends shall also be communicated to the DDC System's local Operator Interface until the District Front End or warranty period is complete.
c. Schedules shall also be available for modification from the local Operator Interface until the District Front End or warranty period is complete.
d. Consult with the District Controls Application Engineer to determine when the local Operator Interface functionality is no longer needed and disable any DDC System communications to the Operator Interface.
2. Graphics – Provide that specified by the A/E for use during system start-up, testing, commissioning, and the warranty period.
3. Alarms
a. Size DDC System controllers so that 48 hours of alarm information minimum can be stored at the building (not including any Operator Interface archiving capacity).
b. Set up alarms so that:
1. They are not issued when the associated system is off (e.g., an alarm for an AHU supply air temperature shall not be issued when the AHU is off).
2. The alarm limits vary with the associated operating mode (e.g., a space temperature's alarm limits changes between occupied and unoccupied modes).
3. The alarm limits vary with the associated set-point (e.g., an AHU supply air or space temperature's alarm limits vary with the set-point if reset).
4. Consult with the District Controls Application Engineer to determine the appropriate alarm limits.
c. The following data shall be associated with each alarm generated/stored by the DDC System:
1. Time and date of the alarm.
2. Alarm Priority
3. Event (alarm) type
4. A text description of the alarm condition including:
a. Location (building, floor, zone, office number, etc.).
b. Equipment (air handler #, pump, etc.).
5. Initiating device and object identifier
6. Acknowledgement time and date
7. Operator who issued acknowledgement.
d. Alarms shall be generated by the DDC System upon the occurrence of one of the following events (in addition to the specified in the Sequence of Operation):
1. Failure of a controller or any other DDC System hardware components.
2. Failure of communications between DDC System components; and between the DDC System and the District Front End, equipment controllers or Subsystems.
3. A monitored status indicating a discrepancy between the actual and the required value.
4. A monitored value does not meet criteria established by the operator.
5. The deviation of a variable from set-point exceeds operator-established criteria.
6. The output to a final control element is outside operator-established criteria.
7. A digital input is in the state defined by the operator as indicating an alarm condition.
8. Software failures and errors shall be diagnosed and annunciated by the BAS.
4. Trending

a. Size DDC System controllers so that 72 hours of trend information minimum can be stored at the building (not including any Operator Interface archiving capacity).
b. Set up trends in each associated General-Purpose Controller for all points using change-of value (COV) trending – consult with the District Controls Application Engineer to select the appropriate COV thresholds for analog points/data:
    1. All Temperature sensors
    2. All Pressure inputs excluding those used to sense flow.
    3. All Humidity sensors
    4. All Gas concentration inputs.
    5. All Current or Voltage inputs
    6. All Flow inputs
    7. Digital input status points
    8. All Analog outputs
    9. Data (virtual points) used for operator override software switches (e.g., for changing operating status of systems and/or used for switching system modes of operation)
c. Set up trends for each of the following Zone Controller, if applicable, using change-of-value (COV) trending:
    1. Space, Supply air and Coil Return Water Temperature
    2. Space/Zone Pressure
    3. Space or Exhaust Humidity
    4. Fan and Heat Pump Status
    5. Air Flow
    6. All Digital input status points
    7. All Occupancy status input points
    8. All Analog output points

5. Point/Data Naming – Use the convention jointly developed with the District Controls Application Engineer.
6. IP Addresses - Addressing shall be set up per the direction of the District Controls Application Engineer.

G. TESTING AND DEMONSTRATION

1. Prior to substantial completion, the control system shall undergo a series of tests to verify and demonstrate operation and compliance with this document. These tests and demonstrations shall occur after the Contractor has completed the installation, started up the system, and performed his own performance tests.
2. The tests and demonstrations described in this section are to be performed in addition to the tests that the Contractor performs as a necessary part of the installation, startup, and debugging process. Control system testing and demonstration shall be scheduled with the District Controls Application Engineer.
3. The Contractor shall provide at least two men equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation, including day, night, summer, winter, occupied, unoccupied, fire/smoke alarm, and power failure modes. The purpose is to evaluate and demonstrate the setup, calibration, response, and action of every point. Any test equipment required to prove the proper operation shall be provided by and operated by the Contractor. The District Controls Application Engineer, and District's HVAC representative shall observe and review these tests.
    a. The system software shall be complete such that each control loop shall function as specified in the Sequence of Operation. This Subcontractor shall be required to furnish the software program and evaluate the operation of every control loop.
    b. After all field connections have been made and control power is available in the control panel, the District Controls Application Engineer shall be notified, and the control system shall be energized. Any required reloading of the software shall be performed and

demonstration of the mechanical system, automatic temperature control system, and other connected systems shall commence.

c. This Subcontractor shall be responsible for all necessary revisions to the software as required to provide a complete and workable system consistent with the letter and intent of the specification. Control performance criteria is specified in the sequence of operations shown on the drawings and/or the specifications.

4. Operational logs for each system which indicate all setpoints, operating points, valve/damper positions, mode, and equipment status shall be submitted to the Architect/Engineer. These logs shall cover a 24-hour period and have a sample frequency of not more than 10 minutes. The logs shall be provided in printed and disk formats.
5. Control loops shall maintain setpoint within the following tolerances:
   a. Airflow ±100 cfm.
   b. Temperature ±1.0°F.
   c. Humidity ±5 percent relative humidity.
   d. Fluid pressure ±2.0 psi range 1 to 150 psi.
   e. ±2.0" w.g. range 0 to 50" differential pressure.
   f. Control loops that do not meet the above tolerances shall be re-tuned.
6. This Contractor shall demonstrate HVAC alarms prior to placing ventilation systems in service.
7. Participate in all tests required between the DDC System and the District Front End. Provide a protocol analyzer (i.e., Wireshark) for use in the testing.
8. The control systems will not be accepted as meeting the Requirements of Completion until all tests and demonstrations described in this section have been performed to the satisfaction of the District Controls Application Engineer.
9. After the system has operated properly for 90 days following startup of the final component of the heating and air conditioning systems, as-built copies of the software on electronic media and a printed copy shall be submitted to the Owner for permanent record purposes. Any software upgrading or enhancements to improve the system operation or as required for proper operation of the system during the first 24 months of operation is the responsibility of this Subcontractor. When changes are made to the software, the Contractor shall immediately provide updated copies of the files on floppy disks.

H. CONTROL EXECUTION – GENERAL

1. Provide independently adjustable, minimum ON and OFF timers for each start/stop point. Initially set times so as not to exceed six (6) starts per hour. On two-speed motors, provide a 20-second adjustable time delay when transferring from high-speed to low-speed, to allow the load to decelerate. This software time delay is in addition to the hardware time delay in the starters.
2. All setpoints, operating points, sequencing ratios, PID tuning parameters, and all other numeric and digital constants shall be adjustable by the user (with a high-level password) from the graphic. To change these values, the user shall not be required to modify program code, recompile, or download.
3. System logs, trend logs, and event-initiated logs shall be set up to provide historical and real-time monitoring of system operation. Logs shall be grouped by equipment.
4. Safety Shutdowns - General: all safety shutdowns of electrical equipment shall be hardwired. All shutdowns shall occur directly through interconnection of contacts on the safety device with the controlling circuit of the electrical equipment. Safety shutdowns through software are not acceptable. Interposing relays may be used only with prior approval of the District Controls Application Engineer when no alternative exists.

I. BAS SOFTWARE

1. Provide sufficient internal memory for the specified control sequences and logging. There shall be a minimum of 25 percent of available memory free for future use.

END OF SECTION

Guide Specifications

Energy Management and Control System

Cherry Creek School District

Setpoint Systems Corporation
8167 SouthPark Circle
Littleton, Colorado 80120

SECTION 23 09 23
DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 - GENERAL

A. SECTION INCLUDES
   1. Related Sections
   2. Description
   3. Approved Control System Contractors and Manufacturers
   4. Quality Assurance
   5. Codes and Standards
   6. System Performance
   7. Submittals
   8. Warranty

B. RELATED SECTIONS
   1. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are a part of this specification and shall be used in conjunction with this section as a part of the contract documents. Consult them for further instructions pertaining to this work. The System Integrator is bound by the provisions of Division 00 and Division 01.
   2. Section 01 33 23 – Shop Drawings, Product Data, and Samples

C. DESCRIPTION
   1. Provide a direct-digital control (DDC) system that will integrate into the Cherry Creek School District (CCSD) district-wide network per the project documents, point list, interoperability tables, drawings, and these specifications. Include all engineering, programming, controls and installation materials, installation labor, commissioning and start-up, training, final project documentation and warranty.
      a. The DDC system shall consist of high-speed BACnet/IP or ethernet, peer-to-peer network of DDC controllers within each building. Each building shall be provided a BBMD and utilize BACnet/SC to provide remote access using any web accessible device to access the control system graphics and change adjustable set points with password protection.
      b. The direct-digital control system shall be BACnet. All new workstations, controllers, devices, and components shall be listed by BACnet Testing Laboratories (BTL) with accessibility using a web browser interface and shall communicate exclusively using the ASHRAE Standard 135 BACnet communications protocol without the use of gateways, unless otherwise allowed by this Section of the technical specifications, specifically shown on the design drawings.
         1) If used, gateways shall support the ASHRAE Standard 135 BACnet communications protocol.
      c. The work administered by this Section of the technical specifications shall include all labor, materials, special tools, equipment, enclosures, power supplies, software, software licenses, project specific software configurations and database entries, interfaces, wiring, tubing, installation, labeling, engineering, calibration, documentation, submittals, testing, verification, training services, permits and licenses, transportation, shipping, handling, administration, supervision, management, insurance, warranty, specified services and items required for complete and fully functional controls systems.

d. The control systems shall be designed such that each mechanical system shall operate under stand-alone mode. The System Integrator administered by this Section of the technical specifications shall provide controllers for each mechanical system. In the event of a network communication failure, or the loss of any field controller, the control system shall continue to operate independently. Failure of the operator workstation(s) (OWS) shall have no effect on the field controllers, including those involved with global strategies.
e. The control system shall be accessible via web browser, no less than 1 OWS, and the control system shall accommodate 10+ web-based users simultaneously, and access to the system should be limited only by operator password. OWS to be provided by owner or SI contractor, project specific.
f. The control system will provide for future expansion to include monitoring of the card access, EPMS, irrigation, and lighting control systems.

D. APPROVED CONTROL SYSTEM INTEGRATORS AND MANUFACTURERS

The following are the approved Control System Integrator and manufacturers:

Company Name/Manufacturer	Address/Location	Contact
Setpoint Systems/Delta Controls	Denver, Colorado	Trey Sellers
TRYG Group		
Trane		

(NOTE: Contact CCSD on a per project basis for approved contractor)

Note:

a. The above list of Control System Integrators and Manufacturers are listed alphabetically and do not display a preference.
b. The Control System Integrator and Manufacture shall use only products from the corresponding manufacturer and product line listed.
c. The above list of manufacturers applies to operator workstation software, controller software, the custom application programming language, building controllers, custom-application controllers, and application-specific controllers. All other products specified herein (e.g., sensors, valves, dampers, actuators, VFDs etc.) need not be manufactured by the above manufacturers.

E. QUALITY ASSURANCE

1. Control System Integrator and Manufacture Qualifications
   a. The Engineer(s), Installer(s), Technician(s), and Project Manager(s) shall have an established working relationship with the Control System Manufacturer of not less than three (3) years.
   b. The Engineer(s), Installer(s), Technician(s), and Project Manager(s) shall have successfully completed Control System Manufacturer's classes on the control system and shall have documented certification from the manufacture. The Engineer(s), Installer(s), Technician(s), and Project Manager(s) shall present for review the certification of completed training, including the hours of instruction and course outlines upon request.
   c. All products used in this installation shall be new, currently under manufacture, and shall be applied in similar installations for a minimum of 2 years. This installation shall not be used as a test site for any new products unless explicitly approved by the Cherry Creek School District in writing. Spare parts shall be available for at least 5 years after completion of this contract. SI contractor responsible to make CCSD aware of any known products that are being phased out or the verge of becoming obsolete.

F. CODES AND STANDARDS
1. All work, materials, and equipment shall comply with the rules and regulations of all codes and ordinances of the local, state, and federal authorities. Such codes, when more restrictive, shall take precedence over these plans and specifications. As a minimum, the installation shall comply with the current editions in effect 30 days prior to receipt of bids of the following codes and standards:
   a. National Electric Code (NEC)
   b. International Building Code (IBC)
   c. International Mechanical Code (IMC)
   d. ASHRAE 55-2020
   e. ANSI/ASHRAE 62.1-2022
   f. ANSI/ASHRAE/IESNA 90.1-2022
   g. ANSI/ASHRAE 135-2020
   h. ANSI/ASHRAE/USGBC/IES 189.1-2020
   i. BACnet Testing Laboratories Certification (BTL Listed)
   j. UL508A Standard
   k. IEEE 802.1, 802.3
   l. ANSI/TIA/EIA-485-A-1998
   m. CCSD Products and Installation Standards

G. SYSTEMS PERFORMANCE
1. Performance Standards. The system shall conform to the following:
   a. Graphic Display: The system shall display a graphic with 20 dynamic points with all current data within 10 seconds.
   b. Graphic Refresh: The system shall update a graphic with 20 dynamic points with all current data within 5 seconds.
   c. 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 shall start to adjust within 2 seconds.
   d. Object Scan: All changes of state and change of analog values will be transmitted over the high-speed network such that any data used or displayed at a controller or workstation will have been current within the previous 60 seconds.
   e. 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.
   f. Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every 5 seconds. The System Integrator shall be responsible for selecting execution times consistent with the mechanical process under control.
   g. 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.
   h. Multiple Alarm Annunciation: All workstations on the network must receive alarms within 5 seconds of each other.
   i. Network Speed: Minimum 100 Mbps between area and system controllers and all controllers residing on an RS-485/ MSTP network must have a minimum of 76 Kbps.
   j. Reporting Accuracy: The system shall report all values with an end-to-end accuracy as listed as or better than those listed in Table 1.
   k. Stability of Control: Control loops shall maintain measured variable at set point within the tolerances listed in Table 2.

Table 1: Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5ºC [±1ºF]
Ducted Air	±0.5ºC [±1ºF
Outside Air	±1.0ºC [±2ºF]
Dew Point	±1.5ºC [±3ºF]
Water Temperature	±0.5ºC [±1ºF]
Delta-T	±0.15ºC[±0.25ºF]
Relative Humidity	±5% RH
Water Flow	±5% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale.
Air Pressure (ducts)	±25 Pa [±0.1" W.G.]
Air Pressure (space)	±3 Pa [±0.01" W.G.]
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power factor)	5% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO2)	±50 ppm

Note 1: 10%-100% of scale.
Note 2: For both absolute and differential pressure
Note 3: Not including utility-supplied meters.

Table 2: Control Stability and Accuracy

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa [±0.2" w.g.]	0-1.5 kPa [0-6" w.g.]
	±3 Pa [±0.01" w.g.]	-25 to 25 Pa [-0.1 to 0.1" w.g.]
Air flow	±100 cfm	
Temperature	±0.5ºC [±1.0ºF]	
Humidity	±5% RH	
Fluid Pressure	±10 kPa [±1.5 psi]	0-1 kPa [1-150 psi]
	±250 Pa [±1.0" w.g.]	0-12.5 kPa [0-50"w.g.] differential

H. SUBMITTALS
1. Product Data and Shop Drawings: Meet requirements of Section 01xxxx on Shop Drawings, Product Data, and Samples. In addition, System Integrator shall provide shop drawings or other submittals on all hardware, software, and installation to be provided. No work shall begin on any segment of this project until submittals have been reviewed and approved for conformity with the design intent. Two hard copies and one electronic copy are required. All drawings shall be created on AutoCAD Release 2022 or higher and provided on a flash drive. When manufacturer's cutsheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. General catalogs shall not be accepted as cut sheets to fulfill submittal requirements. Submittals shall include:
   a. Building Control System Hardware:
      1) A complete bill of materials of equipment to be used indicating quantity, manufacturer, model number, and other relevant technical data.
      2) Manufacturer's description and technical data, such as performance curves, product specification sheets, and installation/maintenance instructions for the items listed below, and other relevant items not listed below:

i) Direct Digital Controller (controller panels)
ii) Transducers/Transmitters
iii) Sensors (including accuracy data)
iv) Actuators
v) Valves
vi) Relays/Switches
vii) Control Panels
viii) Power Supply
ix) Batteries
x) Operator Interface Equipment

3) Provide floor plans highlighting the locations of all equipment / systems / room sensors and control panel locations.

b. Central System Hardware and Software:
1) A complete bill of material of equipment used indicating quantity, manufacturer, model number, and other relevant technical data.
2) Manufacturer's description and technical data, such as product specification sheets and installation/maintenance instructions for the items listed below and other relevant items not listed below:
i) Computers / Servers
ii) Monitors
iii) Power Supply
iv) Battery Backup/UPS
v) Network Switches
vi) Operating System Software
vii) Operator Interface Software
viii) Graphic Software
ix) Third-party Software
x) License Agreements and Minimum Duration of Warranty
3) Schematic diagrams for all control, communication, and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with function. Show all interface wiring to the control system.
4) Riser/one-line/Architectural diagrams of wiring between all control panels.
5) A list of the color graphic screens (storyboard) to be provided. Provide as a minimum the following:
i) Building rendering and/or campus depiction
ii) Riser/one-line/Architectural diagrams
iii) Flow Diagrams of all equipment/ systems that are controlled and monitored.
iv) Floor plans that identify all locations of equipment and/or systems
v) Each storyboard graphic shall display the following if applicable:
1. Inputs
2. Outputs
3. Set point Adjustment.
4. Schedules
5. Command on/off
6. Programs
7. Trend logs
8. Outside conditions
9. Alarms
10. Datasheets

c. Controlled Systems:

1) A schematic wiring diagram for each controlled system. Each schematic shall have all elements labeled. Where a control element is the same as that shown on the control system schematic, it shall be labeled with the same name. All terminals shall be labeled.
2) An instrumentation list for each controlled system. Each element of the controlled system shall be listed in table format. The table shall show element name, type of device, manufacturer, model number, and product data sheet number.
3) A mounting, wiring, and routing plan view drawing. The design shall take into account HVAC, electrical, and other systems' design and elevation requirements. The drawing shall show the specific location of all concrete pads and bases and any special wall bracing for panels to accommodate this work.
4) A complete description of the operation of the control system, including sequences of operation. The description shall include and reference a schematic diagram of the controlled system.
5) A point list for each system controller including both inputs and outputs (I/O), point number, the controlled device associated with the I/O point, and the location of the I/O device, software flag points, alarm points, spare capacity on blank modules, etc.

2. Schedules:
   a. Within one month of contract award, provide a schedule of the work to Cherry Creek School District facility and construction departments indicating the following:
      1) Intended sequence of work items.
      2) Start dates of individual work items.
      3) Duration of individual work items.
      4) Planned delivery dates for major material and equipment and expected lead times.
      5) Milestones indicating possible restraints on work by other trades or situations.
      6) Provide weekly written status reports indicating work completed, revisions to expect delivery dates, etc. An updated three week look ahead project schedule shall be included. Three week look ahead schedule shall include as a minimum: Manpower loading, major milestones, any and all encumbrances.
3. Project Record Documents: Upon completion of installation, submit three copies of record (as-built) documents. The documents shall be submitted for approval prior to final completion and shall include the following:
   a. Project Record Drawings: These shall be as-built versions of the submittal shop drawings. One set of .pdf and CAD files also shall be provided.
   b. Testing and Commissioning Reports and Checklists: Completed versions of all reports and checklists, along with all trend logs, used to meet the requirements of Part 3: "Control System Demonstration and Acceptance."
   c. Certification of the pressure test required in Part 3: "Control Air Tubing."
   d. Operation and Maintenance (O & M) Manual: This shall include as-built versions of the submittal product data. In addition to the information required for submittals, the O & M manual shall include
      1) Names, addresses, and 24-hour telephone numbers of contractors installing equipment, and the control systems and service representatives of each.
      2) Operator's Manual with procedures for operating the control systems, including logging on/off, alarm handling, producing point reports,

trending data, overriding computer control, and changing set points and other variables.

3) Engineering, Installation, and Maintenance Manual(s) that explain how to design and install new points, panels, and other hardware; preventive maintenance and calibration procedures; how to debug hardware problems; and how to repair or replace hardware.
4) A listing and documentation of all custom software created using the programming language, including the set points, tuning parameters, and object database. One electronic set containing files of the software and database also shall be provided.
5) One electronic set of files of all color graphic screens created for the project.
6) A list of recommended spare parts with part numbers and suppliers.
7) Complete original issue documentation, installation, and maintenance information for all third-party hardware provided, including computer equipment and sensors.
8) Licenses, guarantee, and warranty documents for all equipment and systems.
9) Recommended preventive maintenance procedures for all system components, including a schedule of tasks (inspection, cleaning, calibration, etc.), time between tasks, and task descriptions.

4. Training Manuals: The System Integrator shall provide a course outline and training manuals for all training classes at least six weeks prior to the first class. The Engineer may modify any or all of the training course outline and training materials to meet the needs of the Owner. Review and approval by the Engineer shall be completed at least three weeks prior to the first class.

I. WARRANTY

1. Warrant all work as follows:
   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 System Integrator 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 multiple contracts or a multi-phase contract, then each contract or phase shall have a separate warranty start date and period.

PART 2 - PRODUCTS

A. SECTION INCLUDES
   1. BAS Architecture and General Requirements
   2. Operator Workstation
   3. Building Controllers
   4. Application Specific Controllers
   5. Application Controllers
   6. Point Expansion Module
   7. Building Router
   8. Auxiliary Control Devices - Electronic
   9. Valves
   10. Dampers
   11. Actuators
   12. Transformers, Power Supplies and Line Filtering
   13. Wiring and Raceways
   14. Fiber Optic Cable System
   15. Refrigerant Leak Detection
   16. Sensors/Transmitters
   17. Variable Frequency Drives
   18. Emergency Power Off Switches

B. BAS ARCHITECTURE AND GENERAL REQUIREMENTS
   1. Provide a minimum of one BTL-listed BACnet BBMD DDC Router. More than one DDC Router or Panel may be needed to meet the requirements in the remainder of this paragraph.
   2. All DDC routers/panels shall be connected together by the "DDC Router Network" (BACnet/IP).
   3. Remote Communications: The BAS shall be remotely accessible via an Internet connection provided by others.
   4. A sufficient number of DDC routers/panels/controllers shall be provided to meet the memory needs of the project programming, alarming and trending (24 samples for each point alone, not including that needed for Measurement and Verification (M&V)) along with 25% spare capacity for future use. Point termination types shall include:
      a. Analog Input (AI) – Thermistor, 0-10 VDC or 4-20 mADC
      b. Binary Input (BI) – Monitoring of dry contacts, including contact closure "pulses" up to 10 per second.
      c. Analog Output (AO) - 0-10 VDC, 0-20 VDC or 4-20 mADC.
      d. Binary Output (BO) - Two state DC voltage signal or magnetically held dry contact closure.
   5. Each area, system, and application controller shall continue to execute its control software, sample input points, and update output points without connection to the DDC panel network, Controller network or an operator interface.
   6. See the Sequence of Operation for the specific type of DDC device acceptable for each system/equipment controlled/monitored. General requirements include the following:
      a. An application-specific controller shall not be used for systems/equipment that require custom application programming to meet the Sequence of Operation (i.e., if an application-specific controller is used the factory-provided control software, program must be able to perform the Sequence of Operation without "upper level" control from a DDC panel, etc.).

b. If a DDC controller is listed as acceptable for a system/equipment, the System Integrator may alternatively provide a DDC Router (with point expansion or Panel).

7. Digital Communications to Third-party Controls
   a. The BAS is required to send/receive information via digital communication technologies (e.g. Ethernet/IP, EIA-485); application protocols (e.g., BACnet Modbus) to specified Third-Party controls provided under this or other sections of the specification (e.g. chillers, VFDs, BTU meters, electrical submeters, lighting controls, etc.).
   b. See the Specification sections of the equipment involved (e.g. 25 52 23 for the boilers), the type of communications technology/interface (e.g. the data link layer protocol), and application protocol used by each of the Third-Party controls, and for the list of data to be shared with these controls.
   c. Communications not requiring a gateway (i.e., BACnet): Design the BAS to include the DDC device models (with optional modules if necessary) that provide the necessary data link layer interfaces.
8. Communication Requiring Gateway (i.e., Modbus): Design the BAS to the BAS Controller models (with optional software "drivers" and/or hardware if necessary) that provide the necessary data link layer and application protocol gateway interfaces.

C. OPERATOR WORKSTATION
1. Operator Interference Software - The software shall include the following capabilities:
   a. Graphic screens display of custom graphic screens with dynamic point information and the ability to show animation by shifting image properties based on the status of the point.
      1) NOTE - The terms "graphic screens" and "graphic(s)" in this specification refers to graphical images viewed via a PC running operator interface software (a "thick client") or a PC viewing graphical images on web pages via a web browser (a "thin client").
      2) Graphic Generation: Graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall also provide the capability of capturing or converting graphics from other programs such as AutoCAD.
      3) Graphics Library: Furnish a library of standard HVAC system/equipment graphics screens such as chillers, boilers, air handlers, terminals, fan coils, unit ventilators, etc.; and standard symbols for HVAC components including fans, pumps, coils valves, piping, dampers, ductwork, etc.
2. System Applications- Provide the following:
   a. System Databases Save and Restore: Automatic (when changes occur) and/or manual backup of the system database (e.g., a DDC panel point database and/or control program). The operator shall also be able to manually initiate a download of a specified database to any DDC device in the BAS.
   b. System Configuration: Provide application for BAS configuration (DDC device communications addressing, point definition, etc.).
   c. Help: Provide a context sensitive help system to assist the operator in operation of the BAS.
   d. Security: Each operator shall be required to log on to the BAS with a unique name and password in order to view edit, or delete data. System security level shall be configurable for each operator via the site administrator login.

e. System Diagnostics: the System shall automatically monitor the operation of all DDC devices including network communications and provide an alarm when a failure occurs.
f. Standard BAS Operating Features:
    1) Point/Data Overrides/Modifications: Output points and system data (i.e., set points) shall be modifiable (i.e., auto vs. manual and overridden value) via a link to each item's graphic screen image.
    2) Alarm Processing: An alarm log with acknowledgement and alarm clearing functions, the ability to configure alarm limits, and system reactions (e.g., an alarm message, communications method, etc.).
    3) Trend Logs: The ability to define a custom historical trend log for any data in the system. The data can be displayed tabular or graphical.
    4) Scheduling: A graphical method for scheduling equipment operation including normal, holiday and exception scheduling.
    5) Manage HVAC, lighting and access systems from a single graphic package.
    6) Utilize real time 3-D graphics for building control and visualization.
    7) System must automatically discover newly connected BACnet devices.
    8) System must be able to natively generate reports
    9) System must be capable of printing, texting and emailing alarm notifications.
    10) System must be able to analyze/display no fewer than eight trend logs in a real-time graph.

3. Control Software Editors: The software shall allow for Operator editing of all control applications including the following:
    a. Application Specific Controller: A full screen graphical editor for each type of application that allows the operator to view and change the configuration, name control parameters, and set points for all controllers.
    b. Custom Control Programming: A graphic for creating, modifying, and debugging the custom control programming for all routers/panels controllers.
    c. Graphic Design Software: Software for generating new real-time 3-D graphics for use in the operator workstation. All graphics shall be developed with Delta Controls enteliVIZ HTML5 or approved vendor equal.
4. Web Server: Delta Controls enteliWEB Enterprise Facility and energy Management eWEB-ENT (unlimited I/O, Multiple Sites, Dashboards, Alarms, Basic Energy) or Niagra N4. This shall, as a minimum allow thin clients (PC's running web browser software) to perform all the capabilities described above except Graphic Generation, System Database and Restore, System Configuration, and Control Software Editors.
    a. The software shall support an unlimited number of points and an unlimited amount of thin client users.
    b. Point/Data Overrides/Modifications: Output points and system data (i.e., set points) shall be modifiable (i.e., auto vs. manual and overridden value) via a link to each item's graphic screen image.
    c. Alarm Processing: An alarm log with acknowledgement and alarm clearing functions: and the ability to configure alarm limits, and system reactions (e.g., an alarm message, communications method, etc.).
    d. Trend Logs: The ability to define a custom historical trend log for any data in the system. The time stamp data can be displayed tabular or graphical.
    e. Scheduling: a graphical method for scheduling equipment operation including normal, holiday and exception scheduling.

f. Manage HVAC, lighting and access systems from a single seat front end package.
g. Utilize real time 3-D graphics for building control and visualization.
h. The system is to utilize a Windows based object-oriented navigation system.
i. The system shall allow tenant access to view and adjust local set point as well as view equipment in their space.
j. System must be capable of printing and emailing alarm notifications.
k. System must support multiple languages with the capability for the user to change the language at any time.
l. System must analyze no fewer than eight trend logs in a real-time graph.

5. Historical Data Management: Shall have the capability to record extended periods of data from the DDC system which shall be integrated and viewable within the operator workstation. The historical system should automatically restart following a power failure and will automatically determine the optimal time to back up data from the controllers to minimize data loss. The data should be stored in a SQL database to allow for access from third-party tools.
6. Other requirements:
    a. Acceptable Manufacturers and System Integrators
        1) Only the following manufacturer/system Integrators (representing the product lines, if listed) are acceptable:
            i) Delta Controls installed by Setpoint Systems Corporation
            ii) TRYG Group
            iii) Trane
    b. All BAS components shall be by one of the above manufacturers, except when "controls provided with the unit," "factory-mounted controls," "unit manufacturer provided controls," etc, are referenced by this specification, "BAS Components" includes BAS Panels/Routers/controllers, and operator interface, color-graphics interface, control and programming software. Valves, actuators, sensors, conventional thermostats and other stand-alone controls and other field devices need not be by the same manufacturer.
    c. Third-Party Software: Provide any other software needed for the operation of the operator interface software, such as Microsoft SQL or .NET, .JFS, Excel, etc.

D. BUILDING CONTROLLERS
1. Building Controller is BTL-listed BACnet B-BC device as defined below with non-volatile memory for operating system software; read/write memory for custom programming; communications support for operator interface and the Controller Network.
    a. Delta Controls- eBMGR v4.0
    b. Delta Controls- eBCON v4.0
    c. Delta Controls- DSC-1616E or DSC1212E v3.40
    d. Cbx-8R8-H
    e. CCSD Approved Equivalent
2. Building Controller Network- Provide 100 Mbps BACnet Ethernet/TCP-IP communications (as a master).
3. Controller outputs to have integral HOA switches
4. Owner to approve panel locations
5. Point Termination-building controllers shall provide direct point termination through integral point connections, point expansion and/or point expansion modules.

a. Point expansion shall communicate with the Building Control Panel via the Panel's microprocessor bus (i.e., they shall not use EIA-232/485 and/or any type of LAN technology like MS/TP).
b. A "point Expansion Module" as defined below shall be installed within the same enclosure as the associated Building Control Panel.

E. APPLICATION SPECIFIC CONTROLLERS
1. An application Specific Controller is a BTL- listed BACnet B-AAC or B-ASC device dedicated for use with specific equipment and applications. It shall be provided with the no volatile memory for operating system software; read/write memory for all other purposes; factory-provided control software; and communications support for operator Interface, and the Controller network.
2. Application Specific Controller shall only be used for terminal/zone equipment such as VAV terminal units, constant-volume terminal units, fan coil units, and heat pumps (i.e., when the factory-provided control software meets the Sequence of Operation) or where explicitly allowed by the Sequence of Operation.
   a. ASC's for pressure-independent VAV-terminal-unit control shall have an integral differential pressure sensor for air flow measurement and an integral damper actuator.
3. Each ASC shall have a 76.8Kbps BACnet MS/TP or BACnet/IP Controller Network connection.
4. Acceptable ASC controllers:
   a. Delta Controls- DVC-Vxxx v3.40
   b. Delta Controls- DAC-Vxxx v3.40
   c. Delta Controls- RED5-EDGE-xxx v4.0
   d. Delta Controls- RED5 FIELD-xxx v4.0
   e. Delta Controls- eZNT-xxx v3.40
   f. Delta Controls – Edge v4.0
   g. CBV-2U4-3T
   h. CCSD Approved Equivalent
5. Integral HOA switches are NOT required.
6. Owner to approve panel locations.

F. APPLICATION CONTROLLERS
1. A DDC panel is a BTL-listed BACnet B-BC or B-AAC device with the BACnet options specified below, non-volatile memory for operating system software: 72-hour battery-backed read/write memory for custom control programming, trending, and alarming; integral point or point expansion terminations; and communications support to other DDC routers/panels.
2. DDC Router/panel Network: Provide 100 baseT Ethernet minimum communications with BACnet/IP support for interconnection to other DDC routers/panels, operator interfaces, and to an Internet/intranet connection, if specified.
3. Point Termination-DDC panels shall provide direct point termination through integral point connections, point expansion, and/or point expansion modules.
   a. Point expansion shall communicate with the DDC panel via the Panel's microprocessor bus (i.e., they shall not use EIA-232/485 and/or any type of LAN technology like MS/TP).
   b. A "Point Expansion Module" as defined below shall be installed within the same enclosure as the associated DDC panel.
4. Optional Controller Network- A DDC panel may provide the following:

a. Communications support as a Master to one or more 76.8Kbps BACnet MS/TP data-link layer communications connections for DDC controllers and application-specific controllers.
b. BAC Clause 6 Routing (between the specified DDC Router/Panel and controller Network technologies) and BACnet/IP Broadcast Management (BBMD).

5. Acceptable AAC Controllers:
   a. Delta Controls-DAC-xxxx v3.40
   b. CCSD Approved Equal

G. POINT EXPANSION MODULE
1. A point expansion module provides slaved control (i.e., it does not execute its own control software) via a serial or multi-drop communications connection (e.g., EIA-485, MS/TP, etc.) from a DDC device.
2. A point expansion module cannot be used as a DDC router/panel/controller or Application specific Controller, and shall be mounted within the same enclosure as the DDC router/panel/controller is serves.
3. Acceptable expansion modules
   a. Delta Controls- eBX-xxx v3.40
   b. Delta Controls- DFM-xxx v3.40
   c. Flx-8R-h
   d. CCSD Approved Equal

H. BUILDING ROUTER
1. A Building Panel is BTL-listed BACnet B-BC or B-AAC device with the BACnet options specified below, non-volatile memory for operating system software; 72-hour battery-backed read/write memory for custom control programming, trending, and alarming; real time clock; integral point or expansion terminations; and communications support to other DDC routers/panels.
2. Building Router/Panel Network: Provide 10/100 Mbps Ethernet minimum communications using the BACnet/IP data link layer for interconnection to other DDC routers/panels, operator interfaces, and to an Internet/Intranet connection, if specified.
3. Routing: Provide BACnet Clause 6 Routing (between the specified DDC router and controller network technologies) and BAC/IP Broadcast Management (BBMD).
4. Controller Network: A building router shall be a Master to one or more 10/100 Mbps BACnet DDC controllers and application-specific controllers.
5. Optional Point Termination- Building routers may be utilized for direct point termination through integral point connections, point expansion and/or point expansion modules.
   a. Point expansion shall communicate with the Building Router via the Router's microprocessor bus (i.e., they shall not use EIA-232/485 and/or any type of LAN technology like MS/TP).
   b. A "point expansion module" as defined below shall be installed within the same enclosure as the associated Building Router.
6. Acceptable Building Routers everything with a motor needs a current sensor
   a. Delta Controls- eBMGR-2
   b. CCSD Approved Equal

I. AUXILIARY CONTROL DEVICES - ELECTRONIC
1. Control relays: Plug-in type with dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage suitable for the application.

Electronic relay shall be Functional Device RIBU1C, RIBMU1C, RIBRL1C. No exceptions.

2. Low-Temperature Detection Switches (Freeze-stats): Provide SPDT low temperature-protection thermostats of manual-reset type, with sensing elements of the proper length, but in no case less than 20'-0" in length. Provide thermostat designed to operate in response to coldest 1'-0" length of sensing element, regardless of temperature at other parts of element. Support element properly to cover entire duct width. Provide separate thermostats for each on 25 sf of coil face area or fraction thereof. The setpoint shall be 38F adj unless otherwise specified on the plans or sequence of operations. Siemens, low limit thermostat 134-1504, 15-55° F, manual lockout with remote reset or equivalent by Honeywell.
3. Current Sensing Switches: Use for all motor-status BI point unless otherwise noted; shall be self-powered, solid-state with adjustable trip current. The switch shall be selected to match the current of the application and input requirements of the BAS. Veris Industries Current Switch H608 split core adjustable. For ECM motor applications use Veris Industries HCECM05 current switch. No exceptions
4. Differential Pressure Switches: Used only for duct pressure safety cutoffs unless otherwise noted. Adjustable trip pressure with range suitable for the application. Greystone Differential Pressure switch AFS222, auto reset, 0.5 to 12 inches of water column. No exceptions.
5. On–Off thermostats: Provide thermostats of bi-metal actuated open contact, bellows-actuated enclosed snap-switch type, or equivalent. Provide solid-state type with electrical rating to meet the application. Provide with surface mounted ventilated enclosure. Siemens electric surface mounted thermostat 141-0522. No exceptions.

J. VALVES
1. Control Valves: Provide factory fabricated control valves of appropriate pressure class for the scheduled service. Provide size-modulating valves for a pressure drop, provided by consultant, for water service and 80% of the supply pressure for steam service, unless otherwise noted. Two-position valves shall be line size.
   a. Water Service Values: Equal percentage characteristics with range ability of 50 to 1, and maximum full flow pressure drop of 5 psig.
   b. Single Seated Valves: Cage type trim, providing seating and guiding surfaces for plug on "top and bottom" guided plugs.
   c. Double Seated Valves: Balanced plug type, with cage trim providing seating and guiding surfaces on "top and bottom" guided plugs.
   d. Valve Trim and Stems: Polished stainless steel.
   e. Packing: Spring-loaded Teflon, self-adjusting
   f. Valves: NPS 2-1/2" through 6": Globe valve with bronze body, brass plug flanged ends.
   g. Valves: NPS 2 and smaller: Ball valve with characterized disk, Class 125 forged brass body, brass ball
   h. Belimo valves. No exceptions
2. Butterfly Valves: high performance valves with stainless steel disc and PTFE steel ring shall be used. Body shall be carbon-steel body, 150 lb. full ANSI rated bi-directional, lug style butterfly type, bi-directional dead end pressure rating of 285 psi, and temperature rating of -20 to 300 degrees F. Construction features to include 316 SS electroless nickel plated eccentric rotating disc, dynamic sealed, PTFE seal ring, 17-4 Ph (ASTM A 564 Cind. H1075 or H1100) stainless steel shaft, TFE chevron stem packing SS/DU TFE removal of downstream piping and shall be factory pressure tested to 110% of pressure rating. Valves shall be

installed by use of cap screws; threaded rod not acceptable. Belimo, Keystone or approved equal.

K. DAMPERS
   1. Dampers: AMCA-rated, parallel or opposed-blade design as indicated; 0.108-inch minimum thick, galvanized-steel or 0.125-inch minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades shall not be less than 0.064-inch thick galvanized steel with maximum blade width of 8 inches and length of 48 inches.
      a. Secure blades to 1/2-inch diameter, zinc-plated axles using zinc-plated hardware, with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
      b. Operating Temperature Range: From minus 40 to plus 200 deg F.
      c. Edge Seals, Low-Leakage: Use inflatable blade edging or replaceable rubber blade seals and spring-loaded stainless-steel side seals, rated for leakage at less than 10 cfm per sq. ft. of damper area, at differential pressure of 4-inch wg when damper is held by torque of 50 in. x Ibf; when tested according to AMCA 5000.
      d. Ruskin CD40 or CD50 aluminum. No exception

L. ACTUATORS
   1. Electronic
      a. Design for direct mounting on the device and attachment to the driving shaft (damper actuator only); adjustable angle of rotation or range of actuation; and built in overload protection. Size each motor for 150% of the application requirement and with sufficient reserve power to provide smooth action.
      b. Modulating actuators shall use a 0-10 VDC signal input to match DDC device AO signal output, and 24 VAC power.
      c. Two-position actuators shall be a 24 VAC, two-wire, spring return. Spring actuation return actuation time shall be less than 30 seconds.
      d. Damper Actuators - 90° rotation maximum, with built-in adjustable mechanical stop to limit rotation to that of the damper and/or to meet TAB requirements.
      e. End switches- Provide actuator with integral, adjustable-position indication end switches (one for each fully actuated position) when the actuated device is specified with an end switch binary input point(s). All intake hoods must include end switches.
      f. Belimo Actuators (Series L). No exception
   2. Provide valve actuators capable of close-off against a pressure greater than the respective pump system shut-off head.
   3. Failsafe: Provide spring-return failsafe upon load of power or control signal to the positions as follows:
      a. OA dampers- N.C.
      b. Return-air dampers- N.O.
      c. Relief- and exhaust-air dampers- N.C.
      d. HW Valve – NO
      e. CHW Valve – NC
      f. VAV Box RH Valve - Last

M. TRANSFORMERS, POWER SUPPLIES AND LINE FILTERING
   1. Transformer enclosed Dual 100VA Split-bobbin
      a. Over Current Protection: Circuit Breaker
      b. Temperature: 40° C

c. Approvals: Class 2(UL Approved UL5085-3), UL916, UL508, C-UL, CE, RoHS
d. Main Breaker on/off: Two 100 VA Split-Bobbin Circuit Breaker 50/60 Hz On / Off Switch & Breaker Switch / Breaker (10 Amp) (Kills power to entire unit: Outlets, Aux. Output, & Transformer)* Total Combined Output 9A

2. Power Supply 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% of rated capacity.
   a. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak to peak. Regulation shall be 1.0% line and load combined, with 100 microsecond response time for 50% load changes. Unit shall have built in over-voltage and over-current protection and shall be able to withstand a 150% current overload for at least 3 seconds without trip-out or failure.
      1) Unit shall operate between 0°C and 50°C [32°F and 120°F]. EM/RF shall meet FCC Class B and VDE 0871 for Class B, and MIL-STD 810C for shock and vibration.
      2) Line voltage units shall be UL Recognized and CSA Approved.
      3) TDK Lambda 10W DIN Rail VDC Power Supply DSP10-24. Or approved equal

N. WIRING AND RACEWAYS
1. General: Provide copper wiring, plenum cable, and raceways as specified in the applicable sections of Division 26.
2. All insulated wire to be copper conductors, UL labeled for 90C minimum service
3. All wire shall comply to the following:

Color/Size/Wire	System
Red/18 TFF/MTW Stranded	24VDC Positive
Black/18 TFF/MTW Stranded	24VDC Negative
Blue/14 THHN Stranded	24VAC Hot
White/14 THHN Stranded	24VAC Neutral
Orange/18 TFF/MTW Stranded	Inputs
*Orange/Black Tracer/18 TFF/MTW Stranded	Inputs (ground)
Brown/18 TFF MTW Stranded	Outputs
*Brown/White Tracer/18 TFF/MTW Stranded	Outputs (ground)
Purple/14 THHN Stranded	24VAC Hot Interlock
Gray/14 THHN Stranded	24VAC Neutral Interlock
Black/12 THHN Stranded	120VAC Hot
White/12 THHN Stranded	120VAC Neutral
Blue 24 TSP	MS/TP & Modbus Wiring
Green CAT5 or 6	Ethernet

O. FIBER OPTIC CABLE SYSTEM
1. Optical cable: Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. The sheath shall be UL Listed OFNP in accordance with NEC Section 770. The optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm.
2. Connectors: All optical fibers shall be field terminated with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

P. REFRIGERANT LEAK DETECTION
1. Provide a minimum of one permanently mounted continuously operating refrigerant vapor compound-specific monitor with a pickup/sensor in each chiller

room to detect leakage of refrigerant from locations where the refrigerant is either stored or used.

2. Multiple monitors or monitor pickup points shall be used to limit the distance between the sensor and the refrigerant source to not more than 50 feet. Monitor sampling point(s) shall normally be located 18 inches above the floor in location near the refrigerant source and shall be situated between the refrigerant source and the exhaust fan inlet.
3. Refrigerant monitor shall be capable of detecting concentrations of 1 ppm. It shall be supplied factory calibrated for the applicable refrigerant used in the project and shall coordinate with selected chiller.
4. Monitor shall provide an alarm relay output for each pickup which energizes when the monitor detects a refrigerant level at or above the TLV-TWA. This relay shall be used to energize a flashing light and audible alarm outside the chiller room entrance, as an alarm status input to the BAS, and shall be used to activate the emergency purge ventilation system according to the Sequence of Operation.
5. Monitor shall provide a failure relay output that energizes when the monitor detects a fault in its operation. Faults include low air flow through the monitor, circuit failure, and a saturated or absent sensor signal.
6. Monitor shall be certified to UL 2075 and CSA 22.2
7. Approved Manufacturers/Products- MSA Chillgard RT Refrigerant Monitor or approved equal.

Q. SENSORS/TRANSMITTERS

1. Temperature Sensors: Thermistor or RTD with a minimum accuracy of +/0.5 degrees F throughout the specified temperature range.
   a. Duct: Utilize a capillary type (20’ min.) averaging sensors for all mixing box applications and supply ducts with a cross sectional area in excess of 20 square feet; 0 to 100°F range. Greystone Average sensors four analog average, high, low or two difference output 6N1-ISO. No exceptions.
   b. Outside Air: -30°F to 120°F range. Watertight inlet fitting shielded from direct sunlight. Greystone OSA c/w sunshield/windshield TE200F7. No exceptions.
   c. Pipe: 20 to 220 degrees F. Immersion style with thermowells: Series 300 Stainless steel for steam lines; stainless steel of brass, for water lines. Greystone Duct Sensor Greystone Duct/ immersion temperature sensor with ABS enclosure DTS-ABS2. No exceptions.
   d. Space: Surface-mounted, ventilated enclosure with set point adjustment, unoccupied-mode override button, and temperature indication. Space sensors used for terminal unit control shall have an integral part that is connected to the corresponding controller’s operator interface port. 50 to 90 degrees F. range.
   e. Public Spaces (excluding gym): Greystone space temp sensor 10K stainless steel flat plate sensor TE200AS7. No exceptions.
   f. Gym (Single Zone Units): Stainless Steel flat plate sensor with CO2 in return air duct
2. Flow Elements/Transducers:
   a. VAV terminal Unit: Provide differential-pressure transducer integral to the application-specific controller. Connect to pitot-tube element provided with terminal unit.
   b. Chilled Water or Condenser Water Flow: Onicon F3500 electromagnetic flow meter. No substitutes.

3. Differential Pressure Sensors: Differential pressure sensors (air or water) shall be temperature compensated with an accuracy of +/-1% of range and hysteresis of 0.5% of range. Jumper selectable ranges; Veris PX3 no exceptions

   Duct static 0 to 5", Bldg Static -0.25 to +0.25, Mixed Air Plenum -0.25 to +0.25, Return/Mixed Air Plenum -1" to 1" *reference to product table ranges.
   a. Air: Sensor shall be able to withstand a maximum port pressure of 10psig.
   b. Water: Wetted parts shall be stainless steel; sensor shall be able to withstand a maximum port pressure of 250psig and a maximum differential pressure of 150psi or 300% of the rated range, whichever is greater. Add: digital readout; service ports built-in
4. Airflow Measuring Station:
   a. Shall be a thermal dispersion airflow sensor.
   b. An accuracy of +/- 2% for airflow
   c. Shall include an integrated LCD display.
   d. Shall include manual controls for sensor settings and configurations.
   e. Network connectivity shall be BACnet/IP, Ethernet, or MS/TP
   f. Approved Manufacturers: EBTRON; no exceptions
5. Carbon Monoxide (CO) Controllers (for Parking Garage CO Purge, Boiler rooms)
   a. Combination controller/sensor or separate controller with multiple remote-mounted sensors. Design shall be for room (not duct) applications. Greystone CMD5B4000 sensor or approved equal.
   b. Each controller shall have an integral LCD, dry contact alarm relay, and buzzer.
   c. Provide one controller per parking level minimum (per 5,000 SF) (applicable to controller with separate remote-mounted sensors only).
   d. Provide a sufficient number of controller/sensors or sensors based on the manufacturer coverage data.
   e. Set the unit to close the alarm relay based on the manufacturer-recommended time-based set points needed to meet all applicable codes/standards.
6. Carbon Dioxide (CO2) Sensors
   a. Provide non-dispersive infrared (NDIR), Diffusion sampling CO2 sensors with integral transducers and linear output. Linear, CO2 Concentration Range Display: 0 to 2000 ppm.
   b. Accuracy: Plus/minus 2 percent of measured value, measured at NTP.
   c. Repeatability: Plus/minus 20 ppm or plus/minus 2 percent of measured value.
   d. Response time: less than 60 seconds for 90 percent step change.
   e. Output: analog 4-20mA.
   f. Air Temperature: range of 32 to 122 degrees F.
   g. Relative Humidity: Range of 0 to 95 percent (non-Condensing).
   h. Power Input: Class 2; 12 to 30VDC or 24VAC 50/60 Hz; 100mA max
   i. Calibration characteristics: Automatically compensating algorithm for sensor drift due to sensor degradation, Maximum Drift: 2 percent.
   j. Greystone duct sensor CO2 CDD4A200, Greystone space CO2 sensor CMD5B4000. No Exceptions or approved equal.

R. VARIABLE FREQUENCY DRIVE
1. Where shown on the drawings, adjustable frequency drives 0.50 through 800 HP shall have the following features:
   a. The VFD shall provide microprocessor-based control for three-phase induction motors. The controller's full load output current rating shall be

based on a low overload application at 40□ C ambient and 1.5 - 10 kHz switching frequency with automatic switching frequency de-rating in case of overload.

b. The VFD's shall be of the Pulse Width Modulated (PWM) design converting the utility input voltage and frequency to a variable voltage and frequency output via a two-step operation. Adjustable Current Source VFD's are not accepted. Insulated Gate Bipolar Transistors (IGBTs) shall be used in the inverter section. Bipolar Junction Transistors, GTOs are not accepted. The VFD shall run at the above listed switching frequencies.
c. The VFD's shall have an efficiency at full load and speed that exceeds 97%. The efficiency shall exceed 90% at 50% speed.
d. The VFD's shall maintain a minimum line side displacement power factor of 0.96, regardless of speed and load for VFD's less than 75 HP. The VFD's shall maintain a minimum line side displacement power factor of .99, regardless of speed and load for motors greater than 75 HP.
e. The VFD's shall have a one (1) minute overload current rating of 110% for low overload applications.
f. The VFD's shall be capable of operating any NEMA design B squirrel cage induction motor, regardless of manufacturer, with a horsepower and current rating within the capacity of the VFD.
g. The VFD's shall have an integral EMI/RFI filter as standard.
h. VFD must contain a circuit breaker, fused disconnect is not acceptable.
i. When requested, harmonic calculations shall be done based on the kVA capacity, X/R ratio and the impedance of the utility transformer feeding the installation, as noted on the drawings, and the total system load. The calculations shall be made with the point of common coupling (PCC) being the point where the utility feeds multiple customers.
j. Total harmonic distortion shall be calculated based on total demand distortion conditions as defined in IEEE 519-1992. Copies of these calculations are to be made available upon request. The System Integrator shall provide any needed information to the VFD supplier three (3) weeks prior to requiring harmonic calculations.
k. The VFD's shall be able to start into a spinning motor. The VFD's shall be able to determine the motor speed in any direction and resume operation without tripping. If the motor is spinning in the reverse direction, the VFD's shall start into the motor in the reverse direction, bring the motor to a controlled stop, and then accelerate the motor to the preset speed.
l. VFDs must include ground shaft kit.
m. Standard operating conditions shall be:
    1) Incoming Power: Three-phase, 208 / 230 / 480 (+10% to -10%) and 50/60 Hz (+10 to -5%) power to a fixed potential DC bus level.
    2) Frequency stability of +/-0.05% for 24 hours with voltage regulation of +/-1% of maximum rated output voltage.
    3) Speed regulation of +/- 0.5% of base speed.
    4) Load inertia dependent carryover (ride through) during utility loss.
    5) Insensitive to input line rotation.
    6) Humidity: 0 to 95% (non-condensing and non-corrosive).
    7) High Altitude: 1000 meters above sea level.
    8) Ambient Temperature: -10 to 40 □C (VT).
    9) Storage Temperature: -40 to 70 □C.
n. Control Features
    1) Keypad

i) Frequently accessed VFD programmable parameters shall be adjustable from a digital operator keypad located on the front of the VFD. Keypads must use plain English words for parameters, status, and diagnostic messages. Keypads that are difficult to read or understand are not accepted, and particularly those that use alphanumeric code and tables. Keypads shall be adjustable for contrast with large characters easily visible in normal ambient light.

ii) The VFD shall include a Hand-Off-Auto selection and an Inverter/Bypass selection. When in "Hand" the VFD will be started, and the speed will be controlled from the keypad. When in "Off", the VFD will be stopped. In "Auto", the VFD will start via an external contact closure or a communication network and the VFD speed will be controlled via an external speed reference.

iii) The keypad shall have copy / paste capability.

iv) Upon initial power up of the VFD, the keypad shall display a start-up guide that will sequence all the necessary parameter adjustments for general start up.

v) Standard advanced programming and trouble-shooting functions shall be available by using a personal computer's USB port and Windows™ based software. In addition, the software shall permit control and monitoring via the VFD's RS485 port. The manufacturer shall supply the required software. An easily understood instruction manual and software help screens shall also be provided. The computer software shall be used for modifying the drive setup and reviewing diagnostic and trend information as outlined in this section through section 18.

vi) The operator shall be able to scroll through the keypad menu to choose between the following:

1. Monitor
2. Parameters
3. Diagnostics
4. I/O and Hardware
5. User Settings
6. Favorites
7. Direct Access ID

2) The following setups and adjustments, at a minimum, are to be available:

i) Start command from keypad, remote and communications port.

ii) Speed command from keypad, remote and communications port.

iii) Motor direction selection

iv) Maximum and minimum speed limits

v) Acceleration and deceleration times, two settable ranges

vi) Critical (skip) frequency avoidance

vii) Torque limit

viii) Multiple attempts restart function.

ix) Multiple preset speeds adjustment

x) Catch a spinning motor start or normal start selection.

xi) Programmable analog output

3) Inputs/Outputs

i) Inputs – A minimum of six (6) programmable digital inputs, two (2) analog inputs shall be provided with the following available as a minimum:

1. Remote HOA Hand/On/Off
2. Remote forward/reverse
3. Remote preset speeds
4. Remote external fault
5. Remote fault reset.
6. Process control speed reference interface, 4-20 mA DC
7. Potentiometer or process control speed reference interface, 0-10V DC
8. RS485 Programming and Operator Interface Port

ii) Outputs – A minimum of two (2) programmable form C Relay outputs, (1) programmable form A Relay output, and (1) programmable analog output shall be provided, with the following available at minimum.

iii) Programmable relay outputs selectable with the following available at minimum:

1. Fault
2. Run
3. Ready
4. Reversing
5. Preset Speed
6. At speed
7. Wrong Direction
8. Damper Control Relay
9. Over temperature Alarm

iv) Programmable analog output signal, selectable with the following available at minimum:

1. Output frequency
2. Frequency reference
3. Motor speed
4. Output current
5. Motor torque
6. Motor power
7. Motor voltage
8. DC link voltage
9. PID controller set point value.
10. PID controller output value
11. PID controller feedback value
12. PID controller error value

4) Capability of two additional expandable I/O interface cards. Upon installation, software shall automatically identify the interface card and activate the appropriate parameters. This should be done without adding any new software.

o. Monitoring and Displays

1) The VFD's display shall be a multi-line graphic type window capable of displaying nine lines of text and the following thirteen (13) status indicators:

i) Run
ii) Forward
iii) Reverse
iv) Stop
v) Ready
vi) Alarm
vii) Fault

viii) I/O Terminal
ix) Keypad
x) Fieldbus
xi) Hand
xii) Auto
xiii) Off

2) The VFD's keypad shall be capable of displaying the following monitoring functions at a minimum and be able to monitor any nine of them on a single screen:
i) Motor Speed (RPM and %)
ii) Analog Input 1
iii) Analog Input 2
iv) Output frequency
v) Motor current
vi) Motor torque
vii) Motor power (kW and %)
viii) Motor voltage
ix) DC-link voltage
x) Heat sink temperature.
xi) Motor temperature
xii) Run time hours (resettable)
xiii) Power on hours (resettable)
xiv) Total megawatt hours
xv) Megawatt hours (resettable)
xvi) Digital inputs status
xvii) Analog and relay outputs status
xviii) PID references

3) The VFD's keypad shall be able to measure in the following units:
i) Temperature in Fahrenheit
ii) Temperature in Celsius
iii) PSIG
iv) BAR
v) FEET
vi) Inches of Water Column
vii) Gallons per minute
viii) Feet per minute
ix) Cubic Feet per minute
x) Parts per Million
xi) %

p. Protective Functions
1) The VFD shall include the following protective features at minimum:
i) Overcurrent
ii) Overvoltage
iii) System fault
iv) Undervoltage
v) Input line supervision.
vi) Output phase supervision.
vii) Under temperature
viii) Overtemperature
ix) Motor stalled.
x) Motor over temperature
xi) Motor under load

2) The VFD shall provide ground fault protection during power-up, starting, and running. VFD's with no ground fault protection during running are not accepted.

q. Diagnostic Features
   1) Active Faults
      i) The last 10 faults shall be recorded and stored in sequential order.
      ii) Fault name and description of fault shall be displayed on the keypad.
      iii) Fault or alarm display shall blink.
      iv) Display drive data at time of fault (including date and time of occurrence)
      v) In the event several faults occur simultaneously, the sequence of active faults shall be viewable.
      vi) During a fault, the drive must be able to identify the following:
         1. Code
         2. ID
         3. State
         4. Date
         5. Time
         6. Operating Time
         7. Motor Current
         8. Output Frequency
         9. Output Voltage
         10. DC-Link Voltage
         11. Motor Control Status
         12. Motor Temperature
         13. Heat Sink Temperature
   2) Fault History
      i) The last 40 faults shall be recorded and stored in sequential order.
      ii) Display drive data (including date and time) at time of fault

r. Additional features included in the VFD's:
   1) The current withstand rating of the open VFD shall be 100,000 AIC.
   2) Built in communication capability options shall include BACnet/IP and shall have full communication with Cherry Creek School District's district wide network.
   3) The VFD shall have a cooling fan that is field replaceable using non-screw accessibility.
   4) VFD shall have conformal coated circuit boards for maximum protection of air quality conditions meeting IEC 60068-2-60 requirements. Chemical vapors IEC 60721-3-3, unit in operation class 3C3 and mechanical particles IEC 60721-3-3, unit in operation, class 3S2.
   5) VFD shall not use Electrolytic Capacitors within the power circuit and shall have a minimal maintenance free shelf life of no less than 5 years.
   6) VFD shall have an active (not static V/Hz curve) energy control algorithm to ensure maximum energy savings. VFD software shall include energy optimization algorithm. The software algorithm shall compare output voltage to the motor load. The output voltage is optimized to reduce the motor core losses and maintain a high enough voltage to prevent the motor from becoming unstable.

s. Enclosure
   1) The VFD may be designed in a NEMA Type 1, NEMA 12, or NEMA 3R enclosure. NEMA 4 rated for outdoor VFDs.
   2) The current withstand rating of the enclosed VFD shall be 65,000 AIC.

3) The VFD shall have complete front accessibility with easily removable assemblies.
4) Cable entry shall be top or bottom entry.

t. The VFD manufacturer representative shall provide a three-year warranty on all drives provided and shall maintain engineering service facilities within 75 miles of project to provide start-up service, emergency service calls, repair work, service contracts, maintenance, and training of customer personnel.

u. Refer to section 23.08.10 for approved manufacturer.

S. Emergency Power Off Switches

1. Manual EPO Switch, manual push button

a. Plastic cover required, no break glass.

b. Must be manually reset.

PART 3 - EXECUTION

A. SECTION INCLUDES
   1. Examination
   2. Coordination
   3. Field Quality Control
   4. Wiring
   5. Communication Wiring
   6. Fiber Optic Cable
   7. Installation of Sensors seal conduit that runs pressure like to exterior of Bldg or at AHU/panel
   8. Flow Switch Installation
   9. Actuators
   10. Variable Frequency Drives
   11. Control Panels/Enclosures
   12. Warning Labels
   13. Identification of Hardware and Wiring
   14. Control System Checkout and Testing
   15. Control System Demonstration and Acceptance
   16. Training
   17. Points List
   18. Sequences of Operation

B. EXAMINATION
   1. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the Architect/Engineer for resolution before rough-in work is started.
   2. The System Integrator 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.
   3. The System Integrator 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 System Integrator's work, and the plans and the work of others — the System Integrator shall report these discrepancies to the Engineer and shall obtain written instructions for any changes necessary to accommodate the System Integrator'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 System Integrator to report such discrepancies shall be made by and at the expense of, this System Integrator.

C. COORDINATION
   1. Site
      a. Where the mechanical work will be installed in close proximity to or will interfere with work of other trades, the System Integrator shall assist in working out space conditions to make a satisfactory adjustment. If the System Integrator installs its work before coordinating with other trades, so as to cause any interference with work of other trades, the System Integrator shall make the necessary changes in its work to correct the condition without extra charge.
      b. Coordinate and schedule work with all other work in the same area, or with work which is dependent upon other work, to facilitate mutual progress.
   2. Submittals. Refer to the "Submittals" Section in Part 1 of this specification for requirements.
   3. Test and Balance

a. The System Integrator shall furnish hardware, software, or application tools necessary to interface to the control system for test and balance purposes only.
b. The System Integrator shall provide training in the use of these tools. SI will be available to TAB for assistance as required.
c. In addition, the System Integrator shall provide a qualified technician to assist in the test and balance process until the first four (4) flow devices to be balanced.
d. The tools used during the test and balance process shall be returned to the System Integrator at the completion of the testing and balancing.

4. Life Safety
   a. Duct smoke detectors required for air handler shutdown are supplied under Division 26. The System Integrator shall interlock smoke detectors to air handlers for shutdown as described in Part 3: "Sequences of Operation".
   b. Smoke dampers and actuators required for duct smoke isolation are provided under another Division 25 Section. The System Integrator shall interlock these dampers to the air handlers as described in Part 3: "Sequences of Operation".
   c. Fire/smoke dampers and actuators required for fire rated walls are provided under another Division 25 Section. Control of these dampers shall be by Division 26. The System Integrator shall provide control air to the dampers.
5. Coordination with controls specified in other sections or divisions: Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the System Integrator as follows:
   a. All communication media and equipment shall be provided as specified in Part 2: "Communication" of this specification.
   b. Each supplier of a control's product is responsible for the configuration, programming, startup, and testing of that product to meet the sequences of operation described in this section.
   c. The System Integrator shall coordinate and resolve any incompatibility issues that arise between the control products provided under this Section and those provided under other sections or divisions of this specification.
   d. The System Integrator is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
   e. The System Integrator is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

D. FIELD QUALITY CONTROL
1. All work, materials, and equipment shall comply with the rules and regulations of applicable local, state, and federal codes and ordinances as identified in Part 1 of this specification.
2. System Integrator shall continually monitor the field installation for code compliance, Cherry Creek School District standards and quality of workmanship.

E. WIRING
1. 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.

2. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway per NEC and Division 26 requirements.
3. All low-voltage wiring shall meet NEC Class 2 requirements and shall be color coded per Part 2 of this specification. (Low-voltage power circuits shall be sub-fused when required to meet Class 2 current-limit.)
4. 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.
5. All wiring in mechanical, electrical, or service rooms, or where subject to mechanical damage, shall be installed in raceway minimum of ¾" at levels below 3m [10ft].
6. 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).
7. Do not install wiring in raceway containing tubing.
8. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it, and neatly tied at 3m [10ft] intervals.
9. 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.
10. 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.
11. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
12. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the System Integrator shall provide step-down transformers.
13. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
14. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.
15. Size of raceway and size and type of wire shall be the responsibility of the System Integrator, in keeping with the manufacturer's recommendation and NEC requirements, except as noted elsewhere.
16. Include one pull string in each raceway 2.5 cm [1"] or larger.
17. Use coded conductors throughout with different-colored conductors per Part 2 of this specification.
18. Control and status relays are to be in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
19. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15cm [6"] from high-temperature equipment (e.g., steam pipes or flues).
20. 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.
21. Adhere to Division 26 requirements where raceway crosses building expansion joints.

22. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.
23. Wire installed through ribbed penetrations must be contained in conduit.
24. In insulated areas, wire must be installed in conduit.
25. The System Integrator shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
26. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 1 m [3 ft] in length and shall be supported at each end. Flexible metal raceway less than ½" 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.
27. 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.
28. Any conduit 1" or greater requires as built documentation.

F. COMMUNICATION WIRING
1. The System Integrator shall adhere to the items listed in the "Wiring" Section in Part 3 of the specification.
2. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.
3. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.
4. Maximum pulling, tension, and bend radius for cable installation as specified by the cable manufacturer shall not be exceeded during installation.
5. System Integrator shall verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.
6. 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.
7. All runs of communication wiring shall be unspliced length when that length is commercially available.
8. All communication wiring shall be labeled to indicate origination and destination data.
9. Grounding of coaxial cable shall be in accordance with NEC regulations Section on Communications Circuits, Cable, and Protector Grounding.

G. FIBER OPTIC CABLE
1. Maximum pulling tensions as specified by the cable manufacturer shall not be exceeded during installation. Post-installation residual cable tension shall be within cable manufacturer's specifications.
2. All cabling and associated components shall be installed in accordance with manufacturers' instructions. Minimum cable and unjacketed fiber bend radii as specified by cable manufacturer shall be maintained.
3. All fiber optic cable shall be labeled to indicate origination and destination data.

H. INSTALLATION OF SENSORS
1. Install sensors in accordance with the manufacturer's recommendations and shall be labeled to indicate origination, destination data, point name and address.
2. Mount sensors rigidly and adequately for the environment within which the sensor operates.

3. Room temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.
4. All wires attached to sensors shall be air sealed in their raceways or in the wall to stop air transmitted from other areas affecting sensor readings.
5. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across duct. Each bend shall be supported with a capillary clip.
6. Low limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m of sensing element for each 1 m² [1 ft of sensing element for each 1 ft²] of coil area.
7. All pipe-mounted temperature sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid in thermal wells.
8. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.
9. Differential air static pressure. Add: duct pressure tubing that goes onto roof needs to be sealed
    a. Supply Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the high-pressure tap tubing of the corresponding building static pressure sensor (if applicable), or to the location of the duct high-pressure tap and leave open to the plenum.
    b. Return Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.
    c. Building Static Pressure: Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a Bldg static plate.
    d. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer. Rubber caps not acceptable; use nylon.
    e. All pressure transducers, other than those controlling VAV boxes, shall be in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.
    f. All air and water differential pressure sensors shall have gauge tees mounted adjacent to the taps. Water gauges shall also have shutoff valves installed before the tee.
10. All sensors must be installed and accessible for future service, repair, or replacement.

I. FLOW SWITCH INSTALLATION
1. Use correct paddle for pipe diameter.
2. Adjust flow switch in accordance with manufacturer’s instructions; thread sealant as required by manufacturer's instructions.
3. Flow Switch shall be labeled to indicate origination, destination data, point name and address.

J. ACTUATORS
1. Mount and link control damper actuators per manufacturer's instructions.
    a. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.

b. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
c. Provide all mounting hardware and linkages for actuator installation.
d. Actuator shall be labeled to indicate origination, destination data, point name and address.
e. Shaft extensions shall be accessible for repair or replacement.

2. Electric/Electronic
a. Dampers: Actuators shall be direct mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° available for tightening the damper seals. Actuators shall be mounted following manufacturer's recommendations.
b. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.
c. Valves shall be labeled to indicate origination, destination data, point name and address.

3. Pneumatic Actuators
a. Size pneumatic damper actuator to operate the related control damper(s) with sufficient reserve power to provide smooth modulating action or two-position action. Actuator also shall be sized for proper speed of response at the velocity and pressure conditions to which the control damper is subject.
b. Pneumatic damper actuators shall produce sufficient torque to close off against the maximum system pressures encountered. Size the pneumatic damper actuator to close off against the fan shutoff pressure, as a minimum.
c. Where two or more pneumatic damper actuators are installed for interrelated operation in unison, such as dampers used for mixing, provide the dampers with a positive pilot positioner. Positive pilot positioner shall be directly mounted to the pneumatic damper actuator and have pressure gauges for supply input and output pressures.
d. The total damper area operated by an actuator shall not exceed 80% of the manufacturer's maximum area rating. Provide at least one actuator for each damper section. Each damper actuator shall not power more than 2 m² [20 ft²] of damper.
e. Use line shafting or shaft couplings (jack shafting) in lieu of blade-to-blade linkages or shaft coupling when driving axially aligned damper sections.
f. Pneumatic actuators shall be labeled to indicate origination, destination data, point name and address.

K. VARIABLE FREQUENCY DRIVES
1. Bypass to be wired by CCSD.

L. CONTROL PANELS/ENCLOSURES
1. Local control panels:
a. Control panel shall be UL508A.
b. All indoor control cabinets shall be fully enclosed NEMA 1 construction with key-lock latch, removable sub-panels. A single key shall be common to all field panels and sub-panels.
c. Interconnections between internal and face-mounted devices pre-wired with color coded stranded conductors neatly installed in plastic troughs and/or tie wrapped. Terminals for field connections shall be UL Listed for 600-volt service, individually identified per control/interlock drawings, with adequate

clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
   d. All enclosures to be keyed to CCSD specific standard.
   e. Provide ON/OFF power switch with over-current protection for control power sources to each local panel.
   f. Control Panel shall be labeled to match control drawings.
   g. Hard copy of as-builts provided in each enclosure.

M. WARNING LABELS
   1. Permanent warning labels shall be affixed to all equipment which can be automatically started by the DDC system.
      a. Labels shall use white lettering (12-point type or larger) on a red background.
      b. Warning labels shall read as follows:

C A U T I O N
This equipment is operating under automatic control
And may start or stop at any time without warning.
Switch disconnect to the off position before servicing.

   2. Permanent warning labels shall be affixed to all motor starters and all control panels which are connected to multiple power sources utilizing separate disconnects.
      a. Labels shall use white lettering (12-point type or larger) on a red background.
      b. Warning labels shall read as follows:

C A U T I O N
This equipment is fed from more than one
power source with separate disconnects.
Disconnect all power sources before servicing.

N. IDENTIFICATION OF HARDWARE AND WIRING
   1. All wiring and cabling, including that within factory-fabricated panels, shall be labeled at each end within 5 cm [2"] of termination with the DDC address or termination number.
   2. All pneumatic tubing shall be labeled at each end within 5 cm [2"] of termination with a descriptive identifier.
   3. Permanently label or code each point of field terminal strips to show the instrument or item served.
   4. Identify control panels with minimum 1 cm [½”] letters on laminated plastic nameplates.
   5. Identify all other control components with permanent labels. All plug-in components shall be labeled such that removal of the component does not remove the label.
   6. Identify room sensors relating to terminal box or valves with nameplates.
   7. Manufacturers' nameplates and UL or CSA labels to be visible and legible after equipment is installed.
   8. Identifiers shall match record documents/ control drawings.

O. CONTROL SYSTEM CHECKOUT AND TESTING
   1. Startup Testing: All testing listed in this section shall be performed by the System Integrator and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the Owner’s Representative is notified of the system demonstration.

2. The System Integrator shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
3. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
4. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures per manufacturers' recommendations.
5. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
6. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start, and span are correct, and that direction and normal positions are correct. The System Integrator shall check all control valves and automatic dampers to ensure proper action and closure. The System Integrator shall make any necessary adjustments to valve stem and damper blade travel.
7. Verify that the system operation adheres to the Sequences of Operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops and optimum Start/Stop routines.
8. Alarms and Interlocks:
    a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
    b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
    c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.
9. Trends
    a. Check each trend log separately for configuration and correctness.
    b. Check that each physical point is being trended.

P. CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE
1. Demonstration
    a. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the System Integrator has completed the installation, started up the system, and performed its own tests.
    b. The tests described in this section are to be performed in addition to the tests that the System Integrator performs as a necessary part of the installation, startup, and debugging process and as specified in the "Control System Checkout and Testing" Section in Part 3 of this specification. The Engineer will be present to observe and review these tests. The Engineer shall be notified at least 10 days in advance of the start of the testing procedures.
    c. The demonstration process shall follow that approved in Part 1: "Submittals." The approved checklists and forms shall be completed for all systems as part of the demonstration.
    d. The System Integrator shall provide at least two persons equipped with two way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the

proper operation shall be provided by and operated by the System Integrator.

e. As each control input and output is checked, a log shall be completed showing the date, technician's initials, and any corrective action taken or needed.
f. Demonstrate compliance with Part 1: "System Performance."
g. Demonstrate compliance with Sequences of Operation through all modes of operation.
h. Demonstrate complete operation of operator interface.
i. Additionally, the following items shall be demonstrated:
    1) DDC Loop Response: The System Integrator shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop's response to a change in set point which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 10 seconds to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled variable values. Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the System Integrator.
    2) Optimum Start/Stop: The System Integrator shall supply a trend data output showing the capability of the algorithm. The hour-by-hour trends shall include the output status of all optimally started-and-stopped equipment, as well as temperature sensor inputs of affected areas.
    3) Interface to the building fire alarm system where BACnet interface is available.
    4) Operational/trend logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the Architect/Engineer/Cherry Creek School District personnel. These logs shall cover three 48-hour periods and have a sample frequency shall be by change of value and/or time based on not more than 10 minutes. How do I correct Aaron's English to make this make sense
j. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The System Integrator shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.

2. Acceptance
    a. All tests described in this specification shall have been performed to the satisfaction of both the Engineer and Owner prior to the acceptance of the control system as meeting the requirements of Completion. Any tests that cannot be performed due to circumstances beyond the control of the System Integrator may be exempt from the Completion requirements if stated as such in writing by the Engineer. Such tests shall then be performed as part of the warranty.
    b. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in Part 1: "Submittals."

Q. TRAINING
1. Provide a minimum of two on-site or classroom training sessions, two 4-hour days each, throughout the contract period for personnel designated by Cherry Creek School District.

2. Provide two additional training sessions at 6- and 12-months following building's turnover. Each session shall be four hours in length and must be coordinated with Cherry Creek School District.
3. Train the designated staff of Cherry Creek School District Representative to enable them to provide the following:
    a. Day-to-day Operators:
        1) Proficiently operate the system
        2) Understand control system architecture and configuration.
        3) Understand DDC system components.
        4) Understand system operation, including DDC system control and optimizing routines (algorithms)
        5) Operate the workstation and peripherals.
        6) Log on and off the system.
        7) Access graphics, point reports, and logs.
        8) Adjust and change system set points, time schedules, and holiday schedules.
        9) Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
        10) Understand system drawings, and Operation and Maintenance manual.
        11) Understand the job layout and location of control components.
        12) Access data from DDC controllers and ASCs
        13) Operate portable operator's terminals.
    b. Advanced Operators:
        1) Make and change graphics on the work station.
        2) Create, delete, and modify alarms, including annunciation and routing of these.
        3) Create, delete, and modify point trend logs, and graph or print these both on an ad-hoc basis and at user-definable time intervals.
        4) Create, delete, and modify reports.
        5) Add, remove, and modify system's physical points.
        6) Create, modify, and delete programming.
        7) Add panels when required.
        8) Add operator interface stations.
        9) Create, delete, and modify system displays — both graphical and otherwise
        10) Perform DDC system field checkout procedures.
        11) Perform DDC controller unit operation and maintenance procedures.
        12) Perform workstation and peripheral operation and maintenance procedures.
        13) Perform DDC system diagnostic procedures.
        14) Configure hardware including PC boards, switches, communication, and I/O points.
        15) Maintain, calibrate, troubleshoot, diagnose, and repair hardware.
        16) Adjust, calibrate, and replace system components.
    c. System Managers/Administrators:
        1) Maintain software and prepare backups.
        2) Interface with job-specific, third-party operator software
        3) Add new users and understand password security procedures.
4. These objectives will be divided into three logical groupings. Participants may attend one or more of these, depending on level of knowledge required:
    a. Day-to-day Operators: parts 1-13
    b. Advanced Operators: parts 1-29
    c. System Managers/Administrators: parts 1-13, and 30-32

5. System Integrator shall provide course outline and materials as per "Submittals" Section in Part 1 of this specification. The instructor(s) shall provide one copy of training material per student.
6. The instructor(s) shall be factory-trained and Master Certified instructors experienced in presenting this material.
7. Classroom training shall be done using a network of simulators of working controllers' representative of the installed hardware. Each simulator shall have as a minimum an eBMGR, touch screen, room sensor(s), and application controller with a damper actuator.

R. POINT LIST
1. A points list will be provided for each equipment and/or system to be controlled and/or monitored identified on the construction drawings.

S. SEQUENCE OF OPERATIONS
1. [Provide operation as shown on drawings].

SECTION 23 09 93

SEQUENCES OF OPERATIONS FOR HVAC

PART 1 – GENERAL

A. OVERVIEW

1. This section has been provided as an outline for CCSD standards for the control of mechanical systems. It is the intent of this section to be utilized as a template for temperature control sequences of operation. These sequences shall be utilized to the greatest extent possible, as they apply to individual equipment and system types. Deviation from these sequences of operation shall be reviewed by the District prior to submittal of final construction documents. Items identified with [ ] indicate options to be reviewed and selected.
2. Sections of these guidelines include specific specification requirements in addition to design requirements. The Consulting Engineer shall review these guidelines and incorporate specific specification requirements as needed to meet specific project requirements.
3. The temperature controls for the project shall be assigned by CCSD to the contractor. Consultant shall ensure documentation for temperature controls is identified as being assigned to the contractor by the owner.

B. INTENT
1. This section defines the manner and method by which controls function. Requirements for each type of control system operation are specified. Equipment, devices, and system components required for control systems are specified in other sections.

C. SUBMITTALS GENERAL
1. Consultant shall pay particular attention to the submittals and O&M Manual requirements. In addition to O&M manual data, provide all temperature controls data, including controls components, sequences of operations, control diagrams, and points lists.

D. SUBMITTAL REQUIREMENTS
1. The following requirements shall be included within the project specifications as minimum requirements for temperature controls submittals. Consultant shall ensure these requirements are included within the project manual and associated submittals.
2. Sequence of Operation Documentation: Submit written sequence of operation for entire HVAC system and each piece of equipment.
    a. Preface: 1 or 2 paragraph overview narrative of the system describing its purpose, components, and function
    b. State each sequence in small segments and give each segment a unique number for referencing in Functional Test procedures; provide a complete description regardless of the completeness and clarity of the sequences specified in the contract documents.
    c. Include at least the following sequences:
        1. Start-up.
        2. Warm-up mode.
        3. Normal operating mode.
        4. Unoccupied mode.
        5. Shutdown.
        6. Capacity control sequences and equipment staging.
        7. Temperature and pressure control, such as setbacks, setups, resets, etc.
        8. Detailed sequences for all control strategies, such as economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
        9. Effects of power or equipment failure with all standby component functions.
        10. Sequences for all alarms and emergency shut downs.

11. Seasonal operational differences and recommendations.
12. Interactions and interlocks with other systems.

d. Include initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
e. For packaged controlled equipment, include manufacturer's furnished sequence of operation amplified as required to describe the relationship between the packaged controls and the control system, indicating which points are adjustable control points and which points are only monitored.
f. Include schedules, if known

3. Control System Diagrams: Submit graphic schematic of the control system showing each control component and each component controlled, monitored, or enabled.
   a. Label with settings, adjustable range of control and limits.
   b. Include flow diagrams for each control system, graphically depicting control logic.
   c. Include the system and component layout of all equipment that the control system monitors, enables, or controls, even if the equipment is primarily controlled by packaged or integral controls.
   d. Include draft copies of graphic displays indicating mechanical system components, control system components, and controlled function status and value.
   e. Include all monitoring, control and virtual points specified in elsewhere.
   f. Include a key to all abbreviations.
4. Points List: Submit list of all control points indicating at least the following for each point.
   a. Name of controlled system.
   b. Point abbreviation.
   c. Point description; such as dry bulb temperature, airflow, etc.
   d. Display unit.
   e. Control point or setpoint (Yes / No); i.e., a point that controls equipment and can have its setpoint changed.
   f. Monitoring point (Yes / No); i.e. a point that does not control or contribute to the control of equipment but is used for operation, maintenance, or performance verification.
   g. Intermediate point (Yes / No); i.e., a point whose value is used to make a calculation which then controls equipment, such as space temperatures that are averaged to a virtual point to control reset.
   h. Calculated point (Yes / No); i.e., a “virtual” point generated from calculations of other point values.
5. Project Record Documents: Record actual locations of components and setpoints of controls, including changes to sequences made after submission of shop drawings.

PART 2 – NOT USED

PART 3 – EXECUTION

A. CENTRAL REFRIGERATION SYSTEM(S) SEQUENCES OF OPERATION (SINGLE AIR-COOLED CHILLER)
   1. Description
      a. Chilled water system consists of a single air-cooled chiller and [one][two] variable volume chilled water pumps.
      b. Chilled water coil valves in the system are both 2-way and 3-way valves. 3-way valves utilized to establish minimum system flow. Minimum system flow shall not be set below manufacturer’s minimum chiller flow.
   2. General:
      a. The DDC control system shall interface with manufacturer's chiller control panel. The Control Contractor shall be responsible for all low voltage control wiring associated with

the chiller. The chiller control panel shall provide control over the chillers leaving water temperature based on optimum chiller performance and chilled water reset temperature.
    b. Provide temperature sensors for the outdoor air (with sun shield) and for the chilled water supply and return lines (with immersion wells).
3. System Operation:
    a. Above 65 Degrees F (adj.) the chiller system shall be enabled. Whenever the outside air temperature is below 65 Degrees F (adj.) the chiller system shall be disabled.
    b. Chilled water pump(s) shall run whenever chiller system is enabled.
    c. Chiller operates on internal controls to maintain chilled water set-point.
    d. [Provide chilled water reset to reset the chilled water supply temperature according to the highest demand. Greatest cooling demand shall be determined utilizing valve position. The valve which is open the greatest shall be considered the highest demand.]
    e. [Provide an automatic primary/standby control and fail over function for the chilled water pumps. The primary function of each pump shall be based on a calendar month rotation. When the chilled water pumps are rotated the chiller shall de-energize for a period of 5 minutes (adjustable) prior to actual pump rotation and then re-enable the chiller start circuit only after flow has been proven for the rotated pump. The designated lead pump shall run for a period of 5 minutes after the chiller has cycled off. Provide for start/stop control and positive run indication for each chilled water pump. System pumps shall run for a period of 5 minutes (adjustable) after chilled system is shut down.]
    f. The chilled water system primary pumps shall utilize variable frequency controllers to modulate chilled water system water flow. The VFD's will operate to maintain a designated pressure delta in the chilled water system. The pump's designated pressure delta shall be determined by the amount of water flow required to maintain proper flow across the last coil located the furthest distance from the pumping system. The pressure delta shall be capable of accommodating full flow through this last coil.
4. Operator Station Display:
    a. DDC system graphic.
    b. DDC system status, on-off.
    c. Outdoor-air temperature.
    d. Chilled-water supply temperature
    e. Chilled-water supply temperature set point.
    f. Chilled water return temperature.
    g. Chilled water loop differential pressure.
    h. Chilled water loop differential pressure set point.
    i. Chilled-water pump(s) on-off status.
    j. Chilled-water pump(s) on-off indication.
    k. Chiller General Failure Alarm.
    l. Chiller Status, on-off
    m. CW pump(s) CSR alarm.
    n. CW pump(s) VFD speed.
    o. CW pump(s) VFD enable.
    p. CW pump(s) VFD status/alarm.
    q. Low glycol level alarm

B. CENTRAL REFRIGERATION SYSTEM(S) SEQUENCES OF OPERATION (DUAL AIR-COOLED CHILLERS)
1. Description
    a. Chilled water system consists of a [two][number] air cooled chillers [of equal][of un-equal] size. The chilled water system is configured as a primary/secondary system.
    b. [A single constant volume primary chilled water pump for each chiller][Two constant volume primary pumps each sized for its associated chiller]
    c. [One][Two] variable volume secondary chilled water pumps

d. Chilled water coil valves in the system are both 2-way and 3-way valves. 3-way valves utilized to establish minimum system flow. Minimum system flow shall not be set below manufacturer's minimum chiller flow.
e. Each chiller shall include a motorized isolation valve on the chilled water side to isolate the disabled chiller.

2. General:
   a. The DDC control system shall interface with manufacturer's chiller control panel. The Control Contractor shall be responsible for all low voltage control wiring associated with the chiller. The chiller control panel shall provide control over the chillers leaving water temperature based on optimum chiller performance and chilled water reset temperature.
   b. Provide temperature sensors for the outdoor air (with sun shield) and for the chilled water supply and return lines (with immersion wells).
3. System Operation:
   a. Above 65 Degrees F (adj.) the chiller system shall be enabled. Whenever the outside air temperature is below 65 Degrees F (adj.) the chiller system shall be disabled.
   b. Chilled water primary pump(s) shall run whenever their associated chiller is enabled.
   c. Chilled water secondary pump(s) shall run whenever chilled water system is enabled.
   d. Chiller operates on internal controls to maintain chilled water set-point.
   e. [System monitors chiller capacity from chiller control panel. When lead chiller reaches 95% of total capacity (adjustable), enable second chiller. Chillers shall operate on their internal controls to maintain leaving water setpoint. Whenever chiller capacity of both operating chillers is 45% of total plant capacity, disable lag chiller.]
   f. [System starts smallest chiller first. System monitors chiller capacity from the chiller control panel. When chiller capacity reaches 95% of chiller capacity, system enables larger chiller and disables smaller chiller. Smaller chiller shall run for 5-min (adjustable) after larger chiller is enabled. When larger chiller capacity reaches 95% of chiller capacity, the smaller chiller is enabled and both chillers operate. When total system capacity 90% of either chiller sequence is reversed for chiller shut down.]
   g. [Provide chilled water reset to reset the chilled water supply temperature according to the highest demand. Greatest cooling demand shall be determined utilizing valve position. The valve which is open the greatest shall be considered the highest demand.]
   h. [Provide an automatic lead/lag control and fail over function for the chillers. The primary function of each chiller shall be based on a calendar month rotation. When the chillers are rotated the chiller shall de-energize for a period of 5 minutes (adjustable) prior to actual chiller rotation and then re-enable the chiller start circuit only after flow has been proven for the associated pump. Provide for start/stop control and positive run indication for each chiller.
   i. [Provide an automatic primary/standby control and fail over function for the chilled water pumps. The primary function of each pump shall be based on a calendar month rotation. When the chilled water pumps are rotated the chiller shall de-energize for a period of 5 minutes (adjustable) prior to actual pump rotation and then re-enable the chiller start circuit only after flow has been proven for the rotated pump. The designated lead pump shall run for a period of 5 minutes after the chiller has cycled off. Provide for start/stop control and positive run indication for each chilled water pump. System pumps shall run for a period of 5 minutes (adjustable) after chilled system is shut down.]
   j. The chilled water system primary pumps shall utilize variable frequency controllers to modulate chilled water system water flow. The VFD's will operate to maintain a designated pressure delta in the chilled water system. The pump's designated pressure delta shall be determined by the amount of water flow required to maintain proper flow across the last coil located the furthest distance from the pumping system. The pressure delta shall be capable of accommodating full flow through this last coil.
4. Operator Station Display:

a. DDC system graphic.
b. DDC system status, on-off.
c. Outdoor-air temperature.
d. Chilled-water supply temperature
e. Chilled-water supply temperature set point.
f. Chilled-water return temperature.
g. Chilled water loop differential pressure.
h. Chilled water loop differential pressure set point.
i. Chilled-water pump(s) on-off status.
j. Chilled-water pump(s) on-off indication.
k. Chiller General Failure Alarm.
l. Chiller Status, on-off
m. Chiller Load
n. Chilled Water Plant Load
o. CW pump(s) CSR alarm.
p. CW pump(s) VFD speed.
q. CW pump(s) VFD enable.
r. CW pump(s) VFD status/alarm.
s. Low glycol level alarm

C. CENTRAL REFRIGERATION SYSTEM(S) SEQUENCES OF OPERATION (SINGLE WATER-COOLED CHILLER)
1. Description
a. Chilled water system consists of a single water-cooled chiller, cooling tower, [condenser water sump tank,] [cooling tower bypass valve,] [condenser water system sand filter] [one][two] variable volume chilled water pumps, and [one][two] condenser water pumps.
b. Chilled water coil valves in the system are both 2-way and 3-way valves. 3-way valves utilized to establish minimum system flow. Minimum system flow shall not be set below manufacturer’s minimum chiller flow.
2. General:
a. The DDC control system shall interface with manufacturer's chiller control panel. The Control Contractor shall be responsible for all low voltage control wiring associated with the chiller. The chiller control panel shall provide control over the chillers leaving water temperature based on optimum chiller performance and chilled water reset temperature.
b. Provide temperature sensors for the outdoor air (with sun shield) and for the chilled water supply and return lines (with immersion wells).
3. System Operation:
a. Above 65 Degrees F (adj.) the chiller system shall be enabled. Whenever the outside air temperature is below 65 Degrees F (adj.) the chiller system shall be disabled.
b. Chilled water pump(s) shall run whenever chiller system is enabled.
c. Cooling tower shall be enabled whenever chiller system is enabled.
d. Chiller operates on internal controls to maintain chilled water set-point.
e. [System monitors chiller capacity from chiller control panel. When lead chiller reaches 95% of total capacity (adjustable), enable second chiller. Chillers shall operate on their internal controls to maintain leaving water setpoint. Whenever chiller capacity of both operating chillers is 45% of total plant capacity, disable lag chiller.]
f. [System starts smallest chiller first. System monitors chiller capacity from the chiller control panel. When chiller capacity reaches 95% of chiller capacity, system enables larger chiller and disables smaller chiller. Smaller chiller shall run for 5-min (adjustable) after larger chiller is enabled. When larger chiller capacity reaches 95% of chiller capacity, the smaller chiller is enabled and both chillers operate. When total system capacity 90% of either chiller sequence is reversed for chiller shut down.]

g. [Provide chilled water reset to reset the chilled water supply temperature according to the highest demand. Greatest cooling demand shall be determined utilizing valve position. The valve which is open the greatest shall be considered the highest demand.]
h. Tower Control
    1. Modulate cooing tower fan VFD to maintain condenser water temperature setpoint.
    2. Whenever tower supply water temperature falls below chiller manufacture's minimum chilled water setpoint, modulate tower bypass valve to bypass the tower and maintain minimum condenser water temperature.
    3. Provide automatic tower drain valve to drain cooling tower sump and return water piping whenever outside air temperature falls below 40 deg F. (adjustable).
    4. Condenser water make-up is controlled from [tower][sump tank] water level controls. System monitors condenser water make-up water.
i. Chiller Room Ventilation: The chiller room exhaust fan shall operate whenever space temperature exceeds 85 deg. F. BAS shall monitor fan operation and initiate an alarm for fan failure. Open machine room intake louver whenever exhaust fan operates.
j. Emergency Ventilation: Whenever a leak is detected from the refrigerant monitoring system, open chiller room intake louver. Chiller room exhaust fan shall operate at maximum speed.
k. [Provide an automatic primary/standby control and fail over function for the chilled water pumps. The primary function of each pump shall be based on a calendar month rotation. When the chilled water pumps are rotated the chiller shall de-energize for a period of 5 minutes (adjustable) prior to actual pump rotation and then re-enable the chiller start circuit only after flow has been proven for the rotated pump. The designated lead pump shall run for a period of 5 minutes after the chiller has cycled off. Provide for start/stop control and positive run indication for each chilled water pump. System pumps shall run for a period of 5 minutes (adjustable) after chilled system is shut down.]
l. The chilled water system primary pumps shall utilize variable frequency controllers to modulate chilled water system water flow. The VFD's will operate to maintain a designated pressure delta in the chilled water system. The pump's designated pressure delta shall be determined by the amount of water flow required to maintain proper flow across the last coil located the furthest distance from the pumping system. The pressure delta shall be capable of accommodating full flow through this last coil.
m. Sand Filter Operation: BAS shall enable the sand filter based on weekly (adjustable) time schedule.

4. Safeties:
    a. Emergency EPO switches, located where shown on the mechanical drawings, shall be provided, installed, and wired by the Controls Contractor. The Control Contractor shall provide and wire the low voltage wiring for chiller system control. The EPO switches shall be wired through the BAS system to de-energize the [chiller compressor circuit][all electrically operated equipment within the machine room] and annunciate an alarm at the district Workstation when manually activated. EPO switch shall be low voltage type switch.
    b. BAS shall monitor the refrigerant monitoring system as indicated on the mechanical drawings. Upon activation of the refrigerant monitoring system indicating a refrigerant leak, BAS shall generate an alarm to the district workstation. The BAS shall initiate emergency chiller room exhaust fan control.
5. Operator Station Display:
    a. DDC system graphic.
    b. DDC system status, on-off.
    c. Outdoor-air temperature.
    d. Chilled-water supply temperature
    e. Chilled-water supply temperature set point.

f. Chilled-water return temperature.
g. Chilled water loop differential pressure.
h. Chilled water loop differential pressure set point.
i. Chilled-water pump(s) on-off status.
j. Chilled-water pump(s) on-off indication.
k. Condenser water return temperature.
l. Condenser water supply temperature
m. Cooling tower supply temperature.
n. Cooling tower VFD alarm
o. Cooling tower fan CSR alarm
p. Cooling tower VFD speed
q. Cooling tower fan enable/disable.
r. Sand filter enable/disable.
s. Chiller room space temperature setpoint
t. Chiller room space temperature adjustment
u. Chiller room intake louver open/close
v. Chiller room exhaust fan enable/disable.
w. Chiller room fan emergency high speed enable/disable.
x. Refrigerant detection system alarm
y. Chiller room EPO alarm.
z. Chiller General Failure Alarm.
aa. Chiller Status, on-off
bb. CW pump(s) CSR alarm.
cc. CW pump(s) VFD speed.
dd. CW pump(s) VFD enable.
ee. CW pump(s) VFD status/alarm.
ff. Low glycol level alarm

D. CENTRAL REFRIGERATION SYSTEM(S) SEQUENCES OF OPERATION (DUAL WATER-COOLED CHILLERS)
1. Description
a. Chilled water system consists of multiple water-cooled chillers, [one][two] cooling towers, [condenser water sump tank(s),] [cooling tower bypass valve,] [condenser water system sand filter] [one][two] variable volume chilled water pumps, and [one][two] condenser water pumps.
b. Chilled water coil valves in the system are both 2-way and 3-way valves. 3-way valves utilized to establish minimum system flow. Minimum system flow shall not be set below manufacturer’s minimum chiller flow.
2. General:
a. The DDC control system shall interface with manufacturer's chiller control panel. The Control Contractor shall be responsible for all low voltage control wiring associated with the chiller. The chiller control panel shall provide control over the chillers leaving water temperature based on optimum chiller performance and chilled water reset temperature.
b. Provide temperature sensors for the outdoor air (with sun shield) and for the chilled water supply and return lines (with immersion wells).
3. System Operation:
a. Above 65 Degrees F (adj.) the chiller system shall be enabled. Whenever the outside air temperature is below 65 Degrees F (adj.) the chiller system shall be disabled.
b. Chilled water pump(s) shall run whenever chiller system is enabled.
c. Cooling tower shall be enabled whenever chiller system is enabled.
d. Chiller operates on internal controls to maintain chilled water set-point.
e. [Provide chilled water reset to reset the chilled water supply temperature according to the highest demand. Greatest cooling demand shall be determined utilizing valve position. The valve which is open the greatest shall be considered the highest demand.]

f. Tower Control
    1. Modulate cooing tower fan VFD to maintain condenser water temperature setpoint.
    2. Whenever tower supply water temperature falls below chiller manufacture's minimum chilled water setpoint, modulate tower bypass valve to bypass the tower and maintain minimum condenser water temperature.
    3. Provide automatic tower drain valve to drain cooling tower sump and return water piping whenever outside air temperature falls below 40 deg F. (adjustable).
    4. Condenser water make-up is controlled from [tower][sump tank] water level controls. System monitors condenser water make-up water.
g. Chiller Room Ventilation: The chiller room exhaust fan shall operate whenever space temperature exceeds 85 deg. F. BAS shall monitor fan operation and initiate an alarm for fan failure. Open machine room intake louver whenever exhaust fan operates.
h. Emergency Ventilation: Whenever a leak is detected from the refrigerant monitoring system, open chiller room intake louver. Chiller room exhaust fan shall operate at maximum speed.
i. [Provide an automatic primary/standby control and fail over function for the chilled water pumps. The primary function of each pump shall be based on a calendar month rotation. When the chilled water pumps are rotated the chiller shall de-energize for a period of 5 minutes (adjustable) prior to actual pump rotation and then re-enable the chiller start circuit only after flow has been proven for the rotated pump. The designated lead pump shall run for a period of 5 minutes after the chiller has cycled off. Provide for start/stop control and positive run indication for each chilled water pump. System pumps shall run for a period of 5 minutes (adjustable) after chilled system is shut down.]
j. The chilled water system primary pumps shall utilize variable frequency controllers to modulate chilled water system water flow. The VFD's will operate to maintain a designated pressure delta in the chilled water system. The pump's designated pressure delta shall be determined by the amount of water flow required to maintain proper flow across the last coil located the furthest distance from the pumping system. The pressure delta shall be capable of accommodating full flow through this last coil.
k. Sand Filter Operation: BAS shall enable the sand filter based on weekly (adjustable) time schedule.

4. Safeties:
    a. Emergency EPO switches, located where shown on the mechanical drawings, shall be provided, installed, and wired by the Controls Contractor. The Control Contractor shall provide and wire the low voltage wiring for chiller system control. The EPO switches shall be wired through the BAS system to de-energize the [chiller compressor circuit][all electrically operated equipment within the machine room] and annunciate an alarm at the district Workstation when manually activated. EPO switch shall be low voltage type switch.
    b. BAS shall monitor the refrigerant monitoring system as indicated on the mechanical drawings. Upon activation of the refrigerant monitoring system indicating a refrigerant leak, BAS shall generate an alarm to the district workstation. The BAS shall initiate emergency chiller room exhaust fan control.
5. Operator Station Display:
    a. DDC system graphic.
    b. DDC system status, on-off.
    c. Outdoor-air temperature.
    d. Chilled-water supply temperature
    e. Chilled-water supply temperature set point.
    f. Chilled-water return temperature.
    g. Chilled water loop differential pressure.
    h. Chilled water loop differential pressure set point.

i. Chilled-water pump(s) on-off status.
j. Chilled-water pump(s) on-off indication.
k. Condenser water return temperature.
l. Condenser water supply temperature
m. Cooling tower supply temperature.
n. Cooling tower VFD alarm
o. Cooling tower fan CSR alarm
p. Cooling tower VFD speed
q. Cooling tower fan enable/disable.
r. Sand filter enable/disable.
s. Chiller room space temperature setpoint
t. Chiller room space temperature adjustment
u. Chiller room intake louver open/close
v. Chiller room exhaust fan enable/disable.
w. Chiller room fan emergency high speed enable/disable.
x. Refrigerant detection system alarm
y. Chiller room EPO alarm.
z. Chiller General Failure Alarm.
aa. Chiller Status, on-off
bb. CW pump(s) CSR alarm.
cc. CW pump(s) VFD speed.
dd. CW pump(s) VFD enable.
ee. CW pump(s) VFD status/alarm.
ff. Low glycol level alarm

E. CENTRAL HEATING SYSTEMS(S) SEQUENCES OF OPERATION.
1. Description:
   a. Hot water heating system consists of [two][three][number] condensing hot water boiler(s) and manufacturers boiler management system.
   b. [two][number] variable volume primary heating water pumps with variable frequency drives.
   c. The hot water coil valves in the system are both 2-way and 3-way valves. 3-way valves utilized to establish minimum system flow.
2. General:
   a. The DDC control system shall interface with manufacturer's boiler management system. The Control Contractor shall be responsible for all low voltage control wiring associated with the hot water boilers. The boilers will be furnished with integral flame safe guard switches and low water cut-off switches, which are of the manual reset type. The boiler management system shall provide automatic lead-lag control functions over the boilers. The boiler management system shall also provide control over each boiler's heating water supply temperature based on optimum boiler performance and heating water reset schedule.
   b. The boilers shall be provided with a Boiler Management system (BMS) with a mod bus interface. The BMS system shall be provided with specific boiler alarm status and the DDC system shall include specific alarm points through the BMS. See specification Section 23 52 16 for boiler control interface.
   c. Provide temperature sensors for the outdoor air (with sun shield) and for the hot water supply and return lines (with immersion wells).
3. System Operation:
   a. Above 65 Degrees F (adj.) the boilers shall remain de-energized. Below 65 Degrees F (adj.) the boiler system shall be enabled.
   b. Provide an automatic primary/standby control and fail over function for the hot water pumps. The primary function of each pump shall be based on a calendar month rotation. When the hot water pumps are rotated the boiler shall de-energize for a period of 5

minutes (adjustable) prior to actual pump rotation and then re-enable the boiler start circuit only after flow has been proven for the rotated pump. The designated lead pump shall run for a period of 5 minutes after the boilers have cycled off. Provide for start/stop control and positive run indication for each hot water pump. System pumps shall run for a period of 5 minutes (adjustable) after boiler system is shut down.

c. The boilers and their pump shall run continuously after combustion air flow has been proven open by airflow sensors integral with each boiler.
d. [The BAS system will reset the building's heating water temperature, through the boiler management system, based on an inverse linear relationship based on outside air temperature. The reset schedule shall be:
    1. 0 Deg F – [180 Deg F][160 Deg F]
    2. 60 Deg F – 120 deg F, or manufacturer's minimum.]
e. The heating system primary pumps shall utilize variable frequency controllers to modulate heating system water flow. The VFD's will operate to maintain a designated pressure delta in the hot water heating system. The pump's designated pressure delta shall be determined by the amount of water flow required to maintain proper flow across the last coil located the furthest distance from the pumping system. The pressure delta shall be capable of accommodating full flow through this last coil.

4. Safeties:
    c. Emergency EPO switches, located where shown on the mechanical drawings, shall be provided, installed, and wired by the Controls Contractor. The Control Contractor shall provide and wire the low voltage wiring for boiler system control. The EPO switches shall be wired through the BAS system to de-energize the hot water heating system (boilers and domestic hot water heaters only) and annunciate an alarm at the district Workstation when manually activated. EPO switch shall be low voltage type switch.
5. Operator Station Display:
    a. DDC system graphic.
    b. DDC system status, on-off.
    c. Outdoor-air temperature.
    d. Heating-water supply temperature
    e. Heating-water supply temperature set point.
    f. Heating-water return temperature.
    g. Hot water loop differential pressure.
    h. Hot water loop differential pressure set point.
    i. Heating-water pump(s) on-off status.
    j. Heating-water pump(s) on-off indication.
    k. Boiler General Failure Alarm.
    l. HW pump(s) VFD speed.
    m. HW pump(s) VFD enable.
    n. HW pump(s) VFD status/alarm.
    o. HW pump(s) CSR alarm
    p. EPO alarm.

F. VAV AIR HANDLING UNIT SEQUENCE OF OPERATION
1. Description:
    a. The VAV air handling unit consists of the following system components:
        1. Variable volume supply air fan with VFD
        2. [Return air fan with VFD]
        3. [Unit relief/exhaust air fan with VFD]
        4. [Remotely located relief/exhaust air fan(s) with VFD]
        5. [Remotely located relief/exhaust air hood(s) with motorized dampers]
        6. Motorized return & outside air dampers
        7. [Hot water heating coil]

8. [Pumped hot water heating coil]
9. [Gas heating section]
10. [Chilled water-cooling coil]
11. [DX cooling coil]
12. Outside airflow monitoring station
13. Return air CO2 controls.
14. Duct static pressure controls.

2. General:
   a. The Control Contractor shall also provide DDC VAV terminal unit controllers, sensors, and hot water coil valves for all scheduled VAV terminal units.
   b. The Control Contractor shall connect each controller to the communication network, bind all applicable points, and program each air handling unit controller in accordance with the following sequences.
3. System Control:
   a. Supply Fan Control: Modulate fan speed to maintain duct static pressure setpoint as outlined below. Fan static pressure setpoint shall be determined as pressure required to maintain [1-inch w.c.][x-inch w.c.] at furthest box.
   b. Duct Static Pressure Control:
      1. The BMS shall measure duct static pressure and modulate the supply air fan VFD speed to maintain a duct static pressure setpoint. The speed shall not drop below 10% (adjustable). The static pressure setpoint shall be reset based on zone cooling/heating requirements.
      2. The BMS will modulate the supply air fan air volume to maintain supply air pressure setpoint. The BMS shall directly interface with the supply fan VFD. A duct static pressure sensor located in the supply air ductwork as indicated on the construction drawings. The final location shall be proposed by the TC and submitted to the engineer for final approval.
      3. The BMS monitors the damper position of all VAV terminal units to determine the critical zone (The VAV terminal unit that is the highest percentage open). The goal is to always maintain duct static pressure as low as possible. This is achieved by maintaining the critical zone between 85% and 95% open.
      4. When the critical zone is less than 85% open, the supply fan discharge static pressure resets downward by 0.10” (adjustable), from the previous setpoint, at a frequency of 10 minutes until the critical zone is more than 85% open.
      5. When the critical zone is more than 95% open, the supply fan discharge static pressure resets upward by 0.10” (adjustable), from the previous setpoint, at a frequency of 10 minutes until the critical zone is less than 95% open.
      6. The control bands, setpoint increment values, setpoint decrement values, and adjustment frequencies will be adjusted to optimize static pressure control for stable system operation.
      7. Design duct static pressure setpoint is 1.5”. To always satisfy all zones higher setpoints may be calculated by this routine. These conditions which cause higher setpoints shall be investigated and resolved to allow the system to operate at lower pressures. A maximum setpoint will be set so that a trouble zone will not drive the setpoint beyond a reasonable value. Maximum allowed static pressure is 1.75” (adjustable)
   c. [Return Fan Control: Modulate fan speed to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential pressure sensor as located on the mechanical drawings. Fan tracking shall not be included for building static pressure control.]
   d. [Relief/Exhaust Fan Control: Modulate fan speed to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building

differential pressure sensor as located on the mechanical drawings. Fan tracking shall not be included for building static pressure control.]

e. [Remote mounted Relief/Exhaust Fan Control: Modulate fan speed to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential pressure sensor as located on the mechanical drawings. Fan tracking shall not be included for building static pressure control.]
f. [Relief Hood Control: Modulate relief air damper(s) to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential pressure sensor as located on the mechanical drawings.]
g. Mixed-Air Control: Modulate OA and RA dampers to maintain minimum outside air setpoints as indicated on the equipment schedules in response to outside air airflow as measured from outside airflow monitoring station. CO2 may over-ride minimum airflow setpoints based on minimum/maximum CO2 levels.
h. [Demand Controlled Ventilation (DCV): DCV is enabled and disabled through the BAS. Enable DCV function whenever system is in occupied mode. When the DCV system is enabled the minimum outside air damper position shall be reset between the minimum outside air floor and ceiling positions to maintain the return air CO2 setpoint. The minimum outside air ventilation ceiling value is based on ASHRAE 62.1 calculations incorporating floor area and fully occupied space ventilation requirements. The minimum outside air floor value is based on the ASHRAE 62.1 calculation incorporating floor area ventilation requirements. Outside airflow rates shall be as determined from unit OSA airflow monitoring station. Outside airflow rates are defined as follows:
    1. Absolute CO2 Setpoint (PPM):
    2. Alarm CO2 Setpoint (PPM):
    3. Ventilation Floor Minimum (CFM):
    4. Ventilation Ceiling Minimum (CFM):

    Limit the maximum outside air damper position based on a mixed air temperature low limit of 45 degrees F. (adjustable). Economizer function overrides DCV functions. If CO2 levels exceed maximum CO2 level setpoints, system shall modulate OSA dampers open in 5% airflow increments at 10-minute intervals until CO2 levels drop below maximum setpoint.]
i. [CO2 Reset Mixing Dampers: The CO2 content in each classroom/office/space (as indicated on the construction drawings and its VAV damper position shall be monitored. As necessary, the air handling unit mixing dampers shall be overridden open, to additional outside air, to maintain CO2 levels in said space at required levels.]
j. Economizer: When conditions are favorable (outside air is less than return air), modulate OA and RA dampers to maintain discharge air temperature. When mixed air temperature exceeds SA setpoint enable cooling in conjunction with economizer.
k. [HW Heating Coil: Modulate hot water coil valve to maintain discharge air temperature setpoint.]
l. [Gas Heating Coil: Modulate gas valve to maintain discharge air temperature setpoint.]
m. [HW Coil Circulation Pump: Enable coil circulation pump whenever outside air temperatures are below 65 deg F (adjustable)].
n. [Chilled Water-Cooling Coil: Modulate chilled water coil valve to maintain discharge air temperature setpoint]
o. [DX Cooling Coil: Unit controls stage DX compressors, and [hot gas bypass][variable speed compressor] to maintain discharge air temperature setpoint.
p. Provide discharge air temperature reset based on average zones. Average demand to be determined by a polling of all zones by the BAS and deviation from setpoint.

4. Modes of Operation:
    a. The occupancy mode (occupied-unoccupied) shall be determined through a user-adjustable, graphical, seven-day schedule with an additional holiday schedule.

b. Occupied Mode:
    1. The supply fan shall run continuously.
    2. [Return fan shall run whenever the supply fan runs.]
    3. [Relief/Exhaust fan shall run whenever the supply fan runs.]
    4. [Remote mounted relief/exhaust fan shall run whenever the supply fan runs]
    5. [Relief air dampers shall be enabled whenever the supply fan runs]
    6. Outside air dampers shall be set to minimum position and enable mixed air and economizer functions.
    7. Unit operates as outlined above.
c. Unoccupied Mode:
    1. The supply fan shall be de-energized unless there is a call for heating or cooling in the system by any five (5) zones (adjustable), or if a single zone temperature deviates from temperature of greater than 5 degrees F (adjustable).
    2. [Return fan shall be de-energized. Fan shall only operate whenever supply fan operates as outlined above]
    3. [Relief/Exhaust fan shall be de-energized.]
    4. [Remote mounted relief/exhaust fan shall be de-energized]
    5. [Relief air dampers shall be closed]
    6. Both outdoor air dampers and exhaust dampers shall be closed. The return air damper shall be open.
    7. Unit heating and cooling coils operate as outlined above to maintain discharge air temperature setpoint.
d. Morning Warm-up:
    1. When the outside air temperature is below 55 degrees F, the DDC system shall perform a morning warm-up cycle prior to the occupied mode.
    2. The supply fan shall operate.
    3. [The return fan shall operate]
    4. [The relief/exhaust fan shall not operate]
    5. [The remote mounted relief/exhaust fan shall not operate]
    6. [The relief air dampers shall be closed]
    7. The outside air damper shall be closed, and the return air damper shall be open.
    8. Unit heating coil shall operate as outlined above to maintain discharge air temperature setpoint.
    9. Cooling shall be disabled.
    10. The Air Handling Unit shall remain in the morning warm-up mode until all zones are at their occupied space temperature setpoint. Once all zones are at occupied temperature, enable occupied mode.
e. Morning Cool-down:
    1. When the system is in cooling night setback, the DDC system shall perform a morning cool-down cycle prior to the occupied mode.
    2. If outside air temperature is below average space temperature:
        i. The supply fan shall operate.
        ii. [The return fan shall operate]
        iii. [The relief/exhaust fan shall operate]
        iv. [The remote mounted relief/exhaust fan shall operate]
        v. [The relief air dampers shall be open]
        vi. The outside air dampers shall open and return air damper shall close.
        vii. The cooling and heating systems shall be disabled.
    3. If the outside air temperature is above average space temperature:
        i. The supply fan shall operate.
        ii. [The return fan shall operate]
        iii. [The relief/exhaust fan shall not operate]

iv. [The remote mounted relief/exhaust fan shall not operate]
v. [The relief air dampers shall be closed]
vi. The outside air dampers shall close, and the return air damper shall open.
vii. The cooling system shall be enabled and operate as outlined above to maintain discharge air temperature setpoint.
viii. Heating system shall be disabled.

4. The Air Handling Unit shall remain in the morning cool-down mode until all zones are at their occupied space temperature setpoint. Once all zones are at occupied temperature, enable occupied mode.

5. Safety Interlocks and Overrides:
   a. Smoke Detectors: On the detection of smoke from a duct mounted smoke detector, a hard-wired interlock with the supply fan shall shut down the supply fan and [return fan][relief/exhaust fan][remote relief/exhaust fan(s)] through a signal to the VFD. The unit outside air and [unit relief][remote mounted relief] air dampers shall close. The smoke detector shall furnished and wired by electrical and installed by mechanical. The duct mounted smoke detector shall initiate an alarm to the fire alarm system. Coordinate detector requirements with controls contractor, and fire alarm system provider.
   b. Freezestat located just downstream of the [HW coil][gas heating section] in the air handling unit shall cause the following, upon sensing a temperature less than 38 degrees F (adj.): The supply fan shall stop, [return fan][relief/exhaust fan][remote mounted relief fan] shall stop, all dampers shall close to outside air and the heating valve shall open to 100% or a programmed amount. An alarm shall be initiated to the BAS.
   c. Supply Air Low Limit: Discharge air temperature sensor shall initiate an alarm, close outside air dampers, and modulate [the hot water][gas heating] control valve upon if the supply air temperature drops below 45 degrees F. when unit is in heating mode. Function disabled during cooling mode. This has priority over the needs of discharge air and CO2 control loops.
   d. Duct Static Safety: A manual reset, high limit static pressure switch, located in the supply duct shall shut down the supply fan if it senses a static pressure above 2.5" (adj) WC. Initial high static pressure limit shall be set at 0.5” WC above scheduled external static pressure.
6. Monitor and Alarm Points: The value, binary state, setpoint, voltage, run hours, etc. of any input, output, control loop or virtual point shall be monitored on screen. Terminal mode group information screens shall be provided per the standards required by the District.
7. Operator Station Display:
   a. System occupied/unoccupied mode.
   b. Supply fan on/off indication.
   c. Supply fan current sensing relay alarm.
   d. Supply fan VFD alarm.
   e. Supply fan VFD speed indication.
   f. [Return fan on/off indication]
   g. [Return fan current sensing relay alarm]
   h. [Return fan VFD alarm]
   i. [Return fan VFD speed indication]
   j. [Relief/Exhaust fan on/off indication]
   k. [Relief/Exhaust fan current sensing relay alarm]
   l. [Relief/Exhaust fan VFD alarm]
   m. [Relief/Exhaust fan VFD speed indication]
   n. [Remote mounted Relief/Exhaust fan on/off indication]
   o. [Remote mounted Relief/Exhaust fan current sensing relay alarm]
   p. [Remote mounted Relief/Exhaust fan VFD alarm]
   q. [Remote mounted Relief/Exhaust fan VFD speed indication]

r. [Remote mounted relief hood damper position]
s. Outside air temperature indication
t. Mixed air temperature indication
u. Return air temperature indication.
v. Unit discharge air temperature indication.
w. [Chilled water control valve position]
x. [DX system Enable]
y. [Heating water control valve position]
z. [Gas heating control valve position]
aa. Freeze stat alarm.
bb. Smoke alarm
cc. Outside air setpoint
dd. Outside air indication
ee. Supply air discharge temperature control point adjustment.
ff. Supply static pressure indication.
gg. Supply static pressure control point adjustment.
hh. Building static pressure indication
ii. Building static pressure control point adjustment
jj. [HW coil circulation pump on/off indication]
kk. [HW coil circulation pump current sensing relay alarm]
ll. Unit CO2 level indication
mm. Unit CO2 level control point adjustment.

G. SINGLE ZONE VAV AIR HANDLING UNIT SEQUENCE OF OPERATION
1. Description:
   a. The single zone VAV air handling unit is designed to operate as a single zone air handling unit with variable supply air volumes.
   b. The single zone VAV air handling unit consists of the following system components:
      1. Variable volume supply air fan with VFD
      2. [Return air fan with VFD]
      3. [Unit relief/exhaust air fan with VFD]
      4. [Remotely located relief/exhaust air fan(s) with VFD]
      5. [Remotely located relief/exhaust air hood(s) with motorized dampers]
      6. Motorized return & outside air dampers
      7. [Hot water heating coil]
      8. [Pumped hot water heating coil]
      9. [Gas heating section]
      10. [Chilled water-cooling coil]
      11. [DX cooling coil]
      12. Outside airflow monitoring station
      13. Return air CO2 controls.
2. General:
   a. The Control Contractor shall connect each controller to the communication network, bind all applicable points, and program each air handling unit controller in accordance with the following sequences.
3. System Control:
   a. Supply Fan Control: Fan shall run continuously during occupied periods. Fan cycles during unoccupied periods. Modulate supply air fan to maintain space temperature in conjunction with cooling and heating systems. Initial fan setpoint shall be 30% (adjustable) total supply air volume.
   b. [Return Fan Control: Modulate fan speed to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential

pressure sensor as located on the mechanical drawings. Fan tracking shall not be included for building static pressure control.]

c. [Relief/Exhaust Fan Control: Modulate fan speed to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential pressure sensor as located on the mechanical drawings. Fan tracking shall not be included for building static pressure control.]
d. [Remote mounted Relief/Exhaust Fan Control: Modulate fan speed to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential pressure sensor as located on the mechanical drawings. Fan tracking shall not be included for building static pressure control.]
e. [Relief Hood Control: Modulate relief air damper(s) to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential pressure sensor as located on the mechanical drawings.]
f. Mixed-Air Control: Modulate OA and RA dampers to maintain minimum outside air setpoints as indicated on the equipment schedules in response to outside air airflow as measured from outside airflow monitoring station. CO2 may over-ride minimum airflow setpoints based on minimum/maximum CO2 levels.
q. [Demand Controlled Ventilation (DCV): DCV is enabled and disabled through the BAS. Enable DCV function whenever system is in occupied mode. When the DCV system is enabled the minimum outside air damper position shall be reset between the minimum outside air floor and ceiling positions to maintain the return air CO2 setpoint. The minimum outside air ventilation ceiling value is based on ASHRAE 62.1 calculations incorporating floor area and fully occupied space ventilation requirements. The minimum outside air floor value is based on the ASHRAE 62.1 calculation incorporating floor area ventilation requirements. Outside airflow rates shall be as determined from unit OSA airflow monitoring station. Outside airflow rates are defined as follows:
    1. Absolute CO2 Setpoint (PPM):
    2. Alarm CO2 Setpoint (PPM):
    3. Ventilation Floor Minimum (CFM):
    4. Ventilation Ceiling Minimum (CFM):

    Limit the maximum outside air damper position based on a mixed air temperature low limit of 45 degrees F. (adjustable). Economizer function overrides DCV functions. If CO2 levels exceed maximum CO2 level setpoints, system shall modulate OSA dampers open in 5% airflow increments at 10-minute intervals until CO2 levels drop below maximum setpoint.]
g. [CO2 Reset Mixing Dampers: The CO2 content in the space (as indicated on the construction drawings shall be monitored. As necessary, the air handling unit mixing dampers shall be overridden open, to additional outside air, to maintain CO2 levels in said space at required levels.]
h. Economizer: When conditions are favorable (outside air is less than return air), modulate OA and RA dampers to maintain discharge air temperature. When mixed air temperature exceeds SA setpoint enable cooling in conjunction with economizer.
i. [HW Heating Coil: Modulate hot water coil valve to maintain discharge air temperature setpoint.]
j. [Gas Heating Coil: Modulate gas valve to maintain discharge air temperature setpoint.]
k. [HW Coil Circulation Pump: Enable coil circulation pump whenever outside air temperatures are below 65 deg F (adjustable)].
l. [Chilled Water-Cooling Coil: Modulate chilled water coil valve to maintain discharge air temperature setpoint]
m. [DX Cooling Coil: Unit controls stage DX compressors, and [hot gas bypass][variable speed compressor] to maintain discharge air temperature setpoint.

n. Provide discharge air temperature reset based on space temperature to maintain space temperature setpoint.

4. Modes of Operation:
   a. The occupancy mode (occupied-unoccupied) shall be determined through a user-adjustable, graphical, seven-day schedule with an additional holiday schedule.
   b. Occupied Mode:
      1. The supply fan shall run continuously.
      2. [Return fan shall run whenever the supply fan runs.]
      3. [Relief/Exhaust fan shall run whenever the supply fan runs.]
      4. [Remote mounted relief/exhaust fan shall run whenever the supply fan runs]
      5. [Relief air dampers shall be enabled whenever the supply fan runs]
      6. Outside air dampers shall be set to minimum position and enable mixed air and economizer functions.
      7. Unit operates as outlined above.
   c. Unoccupied Mode:
      1. The supply fan shall be de-energized unless there is a call for heating or cooling in the space.
      2. [Return fan shall be de-energized. Fan shall only operate whenever supply fan operates as outlined above]
      3. [Relief/Exhaust fan shall be de-energized.]
      4. [Remote mounted relief/exhaust fan shall be de-energized]
      5. [Relief air dampers shall be closed]
      6. Both outdoor air dampers and exhaust dampers shall be closed. The return air damper shall be open.
      7. Unit heating and cooling coils operate as outlined above to maintain discharge air temperature setpoint.
   d. Morning Warm-up:
      1. When the outside air temperature is below 55 degrees F, the DDC system shall perform a morning warm-up cycle prior to the occupied mode.
      2. The supply fan shall operate.
      3. [The return fan shall operate]
      4. [The relief/exhaust fan shall not operate]
      5. [The remote mounted relief/exhaust fan shall not operate]
      6. [The relief air dampers shall be closed]
      7. The outside air damper shall be closed, and the return air damper shall be open.
      8. Unit heating coil shall operate as outlined above to maintain discharge air temperature setpoint.
      9. Cooling shall be disabled.
      10. The Air Handling Unit shall remain in the morning warm-up mode until space it at the occupied space temperature setpoint.
   e. Morning Cool-down:
      1. When the system is in cooling night setback, the DDC system shall perform a morning cool-down cycle prior to the occupied mode.
      2. If outside air temperature is below average space temperature:
         i. The supply fan shall operate.
         ii. [The return fan shall operate]
         iii. [The relief/exhaust fan shall operate]
         iv. [The remote mounted relief/exhaust fan shall operate]
         v. [The relief air dampers shall be open]
         vi. The outside air dampers shall open and return air damper shall close.
         vii. The cooling and heating systems shall be disabled.
      3. If the outside air temperature is above average space temperature:

i. The supply fan shall operate.
ii. [The return fan shall operate]
iii. [The relief/exhaust fan shall not operate]
iv. [The remote mounted relief/exhaust fan shall not operate]
v. [The relief air dampers shall be closed]
vi. The outside air dampers shall close, and the return air damper shall open.
vii. The cooling system shall be enabled and operate as outlined above to maintain discharge air temperature setpoint.
viii. Heating system shall be disabled.

4. The Air Handling Unit shall remain in the morning cool-down mode until space is at occupied space temperature setpoint.

5. Safety Interlocks and Overrides:
   a. Smoke Detectors: On the detection of smoke from a duct mounted smoke detector, a hard-wired interlock with the supply fan shall shut down the supply fan and [return fan][relief/exhaust fan][remote relief/exhaust fan(s)] through a signal to the VFD. The unit outside air and [unit relief][remote mounted relief] air dampers shall close. The smoke detector shall furnished and wired by electrical and installed by mechanical. The duct mounted smoke detector shall initiate an alarm to the fire alarm system. Coordinate detector requirements with controls contractor, and fire alarm system provider.
   b. Freezestat: Freezestat located just downstream of the [HW coil][gas heating section] in the air handling unit shall cause the following, upon sensing a temperature less than 38 degrees F (adj.): The supply fan shall stop, [return fan][relief/exhaust fan][remote mounted relief fan] shall stop, all dampers shall close to outside air and the heating valve shall open to 100% or a programmed amount. An alarm shall be initiated to the BAS.
   c. Supply Air Low Limit: Discharge air temperature sensor shall initiate an alarm, close outside air dampers, and modulate [the hot water][gas heating] control valve upon if the supply air temperature drops below 45 degrees F. when unit is in heating mode. Function disabled during cooling mode. This has priority over the needs of discharge air and CO2 control loops.
   d. Duct Static Safety: A manual reset, high limit static pressure switch, located in the supply duct shall shut down the supply fan if it senses a static pressure above 2.5" (adj) WC. Initial high static pressure limit shall be set at 0.5” WC above scheduled external static pressure.
6. Monitor and Alarm Points: The value, binary state, setpoint, voltage, run hours, etc. of any input, output, control loop or virtual point shall be monitored on screen. Terminal mode group information screens shall be provided per the standards required by the District.
7. Operator Station Display:
   a. System occupied/unoccupied mode.
   b. Supply fan on/off indication.
   c. Supply fan current sensing relay alarm.
   d. Supply fan VFD alarm.
   e. Supply fan VFD speed indication.
   f. [Return fan on/off indication]
   g. [Return fan current sensing relay alarm]
   h. [Return fan VFD alarm]
   i. [Return fan VFD speed indication]
   j. [Relief/Exhaust fan on/off indication]
   k. [Relief/Exhaust fan current sensing relay alarm]
   l. [Relief/Exhaust fan VFD alarm]
   m. [Relief/Exhaust fan VFD speed indication]
   n. [Remote mounted Relief/Exhaust fan on/off indication]
   o. [Remote mounted Relief/Exhaust fan current sensing relay alarm]

p. [Remote mounted Relief/Exhaust fan VFD alarm]
q. [Remote mounted Relief/Exhaust fan VFD speed indication]
r. [Remote mounted relief hood damper position]
s. Outside air temperature indication
t. Mixed air temperature indication
u. Return air temperature indication.
v. Unit discharge air temperature indication.
w. [Chilled water control valve position]
x. [DX system Enable]
y. [Heating water control valve position]
z. [Gas heating control valve position]
aa. Freeze stat alarm.
bb. Smoke alarm
cc. Outside air setpoint
dd. Outside air indication
ee. Supply air discharge temperature control point adjustment.
ff. Building static pressure indication
gg. Building static pressure control point adjustment
hh. [HW coil circulation pump on/off indication]
ii. [HW coil circulation pump current sensing relay alarm]
jj. Unit CO2 level indication
kk. Unit CO2 level control point adjustment.

H. PACKAGED SINGLE ZONE AIR HANDLING UNIT SEQUENCE OF OPERATION
1. Description:
   a. The single zone air handling unit is designed to operate as a single zone air handling unit with constant supply air volumes.
   b. The single zone air handling unit consists of the following system components:
      1. Constant volume supply air fan
      2. [Unit relief/exhaust air fan with VFD]
      3. [Remotely located relief/exhaust air fan(s) with VFD]
      4. [Remotely located relief/exhaust air hood(s) with motorized dampers]
      5. Motorized return & outside air dampers
      6. [Hot water heating coil]
      7. [Pumped hot water heating coil]
      8. [Gas heating section]
      9. DX cooling coil
      10. Outside airflow monitoring station
      11. Return air CO2 controls.
2. General:
   a. The Control Contractor shall connect each controller to the communication network, bind all applicable points, and program each air handling unit controller in accordance with the following sequences.
3. System Control:
   a. Supply Fan Control: Fan shall run continuously during occupied periods. Fan cycles during unoccupied periods.
   b. [Relief/Exhaust Fan Control: Modulate fan speed to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential pressure sensor as located on the mechanical drawings. Fan tracking shall not be included for building static pressure control.]
   c. [Remote mounted Relief/Exhaust Fan Control: Modulate fan speed to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from

remote building differential pressure sensor as located on the mechanical drawings. Fan tracking shall not be included for building static pressure control.]

d. [Relief Hood Control: Modulate relief air damper(s) to maintain building static pressure of 0.05 in w.c. (adjustable). Building static pressure is measured from remote building differential pressure sensor as located on the mechanical drawings.]
e. Mixed-Air Control: Modulate OA and RA dampers to maintain minimum outside air setpoints as indicated on the equipment schedules in response to outside air airflow as measured from outside airflow monitoring station. CO2 may over-ride minimum airflow setpoints based on minimum/maximum CO2 levels.
r. [Demand Controlled Ventilation (DCV): DCV is enabled and disabled through the BAS. Enable DCV function whenever system is in occupied mode. When the DCV system is enabled the minimum outside air damper position shall be reset between the minimum outside air floor and ceiling positions to maintain the return air CO2 setpoint. The minimum outside air ventilation ceiling value is based on ASHRAE 62.1 calculations incorporating floor area and fully occupied space ventilation requirements. The minimum outside air floor value is based on the ASHRAE 62.1 calculation incorporating floor area ventilation requirements. Outside airflow rates shall be as determined from unit OSA airflow monitoring station. Outside airflow rates are defined as follows:
    1. Absolute CO2 Setpoint (PPM):
    2. Alarm CO2 Setpoint (PPM):
    3. Ventilation Floor Minimum (CFM):
    4. Ventilation Ceiling Minimum (CFM):

    Limit the maximum outside air damper position based on a mixed air temperature low limit of 45 degrees F. (adjustable). Economizer function overrides DCV functions. If CO2 levels exceed maximum CO2 level setpoints, system shall modulate OSA dampers open in 5% airflow increments at 10-minute intervals until CO2 levels drop below maximum setpoint.]
f. [CO2 Reset Mixing Dampers: The CO2 content in the space (as indicated on the construction drawings shall be monitored. As necessary, the air handling unit mixing dampers shall be overridden open, to additional outside air, to maintain CO2 levels in said space at required levels.]
g. Economizer: When conditions are favorable (outside air is less than return air), modulate OA and RA dampers to maintain discharge air temperature. When mixed air temperature exceeds SA setpoint enable cooling in conjunction with economizer.
h. [HW Heating Coil: Modulate hot water coil valve to maintain discharge air temperature setpoint.]
i. [Gas Heating Coil: Modulate gas valve to maintain discharge air temperature setpoint.]
j. [HW Coil Circulation Pump: Enable coil circulation pump whenever outside air temperatures are below 65 deg F (adjustable)].
k. DX Cooling Coil: Unit controls stage DX compressors, and [hot gas bypass][variable speed compressor] to maintain discharge air temperature setpoint.
l. Provide discharge air temperature reset based on space temperature to maintain space temperature setpoint.

4. Modes of Operation:
    a. The occupancy mode (occupied-unoccupied) shall be determined through a user-adjustable, graphical, seven-day schedule with an additional holiday schedule.
    b. Occupied Mode:
        1. The supply fan shall run continuously.
        2. [Relief/Exhaust fan shall run whenever the supply fan runs.]
        3. [Remote mounted relief/exhaust fan shall run whenever the supply fan runs]
        4. [Relief air dampers shall be enabled whenever the supply fan runs]

5. Outside air dampers shall be set to minimum position and enable mixed air and economizer functions.
6. Unit operates as outlined above.

c. Unoccupied Mode:
1. The supply fan shall be de-energized unless there is a call for heating or cooling in the space.
2. [Relief/Exhaust fan shall be de-energized.]
3. [Remote mounted relief/exhaust fan shall be de-energized]
4. [Relief air dampers shall be closed]
5. Both outdoor air dampers and exhaust dampers shall be closed. The return air damper shall be open.
6. Unit heating and cooling coils operate as outlined above to maintain discharge air temperature setpoint.

d. Morning Warm-up:
1. When the outside air temperature is below 55 degrees F, the DDC system shall perform a morning warm-up cycle prior to the occupied mode.
2. The supply fan shall operate.
3. [The relief/exhaust fan shall not operate]
4. [The remote mounted relief/exhaust fan shall not operate]
5. [The relief air dampers shall be closed]
6. The outside air damper shall be closed, and the return air damper shall be open.
7. Unit heating coil shall operate as outlined above to maintain discharge air temperature setpoint.
8. Cooling shall be disabled.
9. The Air Handling Unit shall remain in the morning warm-up mode until space it at the occupied space temperature setpoint.

e. Morning Cool-down:
1. When the system is in cooling night setback, the DDC system shall perform a morning cool-down cycle prior to the occupied mode.
2. If outside air temperature is below average space temperature:
   i. The supply fan shall operate.
   ii. [The relief/exhaust fan shall operate]
   iii. [The remote mounted relief/exhaust fan shall operate]
   iv. [The relief air dampers shall be open]
   v. The outside air dampers shall open and return air damper shall close.
   vi. The cooling and heating systems shall be disabled.
3. If the outside air temperature is above average space temperature:
   i. The supply fan shall operate.
   ii. [The relief/exhaust fan shall not operate]
   iii. [The remote mounted relief/exhaust fan shall not operate]
   iv. [The relief air dampers shall be closed]
   v. The outside air dampers shall close, and the return air damper shall open.
   vi. The cooling system shall be enabled and operate as outlined above to maintain discharge air temperature setpoint.
   vii. Heating system shall be disabled.
4. The Air Handling Unit shall remain in the morning cool-down mode until space is at occupied space temperature setpoint.

5. Safety Interlocks and Overrides:
a. Smoke Detectors: On the detection of smoke from a duct mounted smoke detector, a hard-wired interlock with the supply fan shall shut down the supply fan and [return fan][relief/exhaust fan][remote relief/exhaust fan(s)] through a signal to the VFD. The unit outside air and [unit relief][remote mounted relief] air dampers shall close. The smoke

detector shall furnished and wired by electrical and installed by mechanical. The duct mounted smoke detector shall initiate an alarm to the fire alarm system. Coordinate detector requirements with controls contractor, and fire alarm system provider.

b. Freezestat: Freezestat located just downstream of the [HW coil][gas heating section] in the air handling unit shall cause the following, upon sensing a temperature less than 38 degrees F (adj.): The supply fan shall stop, [relief/exhaust fan][remote mounted relief fan] shall stop, all dampers shall close to outside air and the heating valve shall open to 100% or a programmed amount. An alarm shall be initiated to the BAS.
c. Supply Air Low Limit: Discharge air temperature sensor shall initiate an alarm, close outside air dampers, and modulate [the hot water][gas heating] control valve upon if the supply air temperature drops below 45 degrees F. when unit is in heating mode. Function disabled during cooling mode. This has priority over the needs of discharge air and CO2 control loops.
d. Duct Static Safety: A manual reset, high limit static pressure switch, located in the supply duct shall shut down the supply fan if it senses a static pressure above 2.5" (adj) WC. Initial high static pressure limit shall be set at 0.5” WC above scheduled external static pressure.

6. Monitor and Alarm Points: The value, binary state, setpoint, voltage, run hours, etc. of any input, output, control loop or virtual point shall be monitored on screen. Terminal mode group information screens shall be provided per the standards required by the District.
7. Operator Station Display:
   a. System occupied/unoccupied mode.
   b. Supply fan on/off indication.
   c. Supply fan current sensing relay alarm.
   d. [Relief/Exhaust fan on/off indication]
   e. [Relief/Exhaust fan current sensing relay alarm]
   f. [Relief/Exhaust fan VFD alarm]
   g. [Relief/Exhaust fan VFD speed indication]
   h. [Remote mounted Relief/Exhaust fan on/off indication]
   i. [Remote mounted Relief/Exhaust fan current sensing relay alarm]
   j. [Remote mounted Relief/Exhaust fan VFD alarm]
   k. [Remote mounted Relief/Exhaust fan VFD speed indication]
   l. [Remote mounted relief hood damper position]
   m. Outside air temperature indication
   n. Mixed air temperature indication
   o. Return air temperature indication
   p. Unit discharge air temperature indication.
   q. DX system Enable
   r. [Heating water control valve position]
   s. [Gas heating control valve position]
   t. Freeze stat alarm
   u. Smoke alarm
   v. Outside air setpoint
   w. Outside air indication
   x. Supply air discharge temperature control point adjustment
   y. Building static pressure indication
   z. Building static pressure control point adjustment
   aa. [HW coil circulation pump on/off indication]
   bb. [HW coil circulation pump current sensing relay alarm]
   cc. Unit CO2 level indication
   dd. Unit CO2 level control point adjustment.

I. MAKE-UP AIR SEQUENCE (MAU-1) [For general systems and systems serving kitchen space and not directly to kitchen hood]
   1. Description:
      a. The air handling unit shall consist of a package make-up air unit with supply air fan, [gas heating section][hot water heating coil][hot water heating coil with coil circulation pump], [and evaporative cooling section].
   2. General:
      a. Unit shall be provided with terminal strip for connection to BAS system by TC contractor.
      b. Unit shall be interlocked with kitchen hood switches and grease exhaust fans to operate whenever kitchen hoods operate.
      c. The Control Contractor shall connect each controller to the communication network, bind all applicable points, and program each unit controller in accordance with the following sequences
   3. System Control – Occupied Periods:
      a. Supply Fan Control: Fan shall run continuously during occupied periods.
      b. OA Control: OA damper opens whenever supply fan runs and kitchen hood is on. [RA damper closes whenever OA damper opens.]
      c. [Gas Heating: Modulate gas valve to maintain discharge air temperature setpoint. When kitchen hoods are operating minimum discharge air setpoint shall be 70 deg. F]
      d. [Hot Water Heating: Modulate temperature control valve to maintain discharge air setpoint. When kitchen hoods are operating minimum discharge air setpoint shall be 70 deg. F]
         1. [Hot water coil circulation pump operates whenever main heating system pumps operate.]
      e. [Evaporative Cooling: Enable evaporative cooling whenever there is a call for cooling. When outside air temperatures are below 50 deg. F enable evaporative cooler drain. When outside air temperatures are above 65 deg. F enable evaporative cooler fill.]
      f. Interlock unit to run whenever any kitchen hood exhaust fan runs.
   4. System Control – Un-Occupied Periods:
      a. Supply Fan Control: Cycle fan to maintain space temperature during un-occupied periods.
      b. OA Control: OA damper remains closed whenever in un-occupied period. RA damper opens whenever in un-occupied period or whenever hood fan is off.
      c. [Gas Heating: Modulate gas valve to maintain discharge air temperature setpoint. When kitchen hoods are operating minimum discharge air setpoint shall be 70 deg. F]
      d. [Hot Water Heating: Modulate temperature control valve to maintain discharge air setpoint. When kitchen hoods are operating minimum discharge air setpoint shall be 70 deg. F]
         1. [Hot water coil circulation pump operates whenever main heating system pumps operate.]
      e. [Evaporative Cooling: Enable evaporative cooling whenever there is a call for cooling. When outside air temperatures are below 50 deg. F enable evaporative cooler drain. When outside air temperatures are above 65 deg. F enable evaporative cooler fill.]
   5. Safety Interlocks and Overrides
      a. Smoke Detector: On the detection of smoke from a duct mounted smoke detector, a hard-wired interlock with the supply fan shall shut down the supply fan through a signal to the unit. The unit outside air dampers shall close. The smoke detector shall furnished and wired by electrical and installed by mechanical. The duct mounted smoke detector shall initiate an alarm to the fire alarm system. Coordinate detector requirements with controls contractor, and fire alarm system provider.
      b. Upon activation of the kitchen hood fire system the unit supply air fan shall de-energize and the outside air damper shall close.

6. Monitor and Alarm Points: The value, binary state, setpoint, voltage, run hours, etc. of any input, output, control loop or virtual point shall be monitored on screen. Terminal mode group information screens shall be provided per the standards required by the District.
7. Operator Station Display:
    a. System on/off indication.
    b. System fan on/off indication.
    c. System fan current sensing relay alarm
    d. Fan discharge air temperature indication.
    e. Fan discharge air temperature setpoint/adjustment.
    f. Evaporative cooling system Enable
    g. Evaporative cooling system drain
    h. Evaporative cooling system fill
    i. Space temperature indication
    j. Space temperature setpoint/adjustment

J. KITCHEN MAKE-UP AIR SEQUENCE (MAU-1) [For systems directly to kitchen hood]
1. Description:
    a. The air handling unit shall consist of a package make-up air unit with supply air fan, [gas heating section][hot water heating coil][hot water heating coil with coil circulation pump], [and evaporative cooling section].
2. General:
    a. Unit shall be provided with terminal strip for connection to BAS system by TC contractor.
    b. Unit shall be interlocked with kitchen hood switches and grease exhaust fans to operate whenever kitchen hoods operate.
    c. The Control Contractor shall connect each controller to the communication network, bind all applicable points, and program each unit controller in accordance with the following sequences
3. System Control – Occupied Periods:
    a. Supply Fan Control: Fan shall run continuously whenever kitchen hood exhaust fan operates. Fan is off whenever kitchen hood fan is off.
    b. OA Control: OA damper opens whenever supply fan runs and kitchen hood is on. [Gas Heating: Modulate gas valve to maintain discharge air temperature setpoint. When kitchen hoods are operating minimum discharge air setpoint shall be 70 deg. F]
    c. [Hot Water Heating: Modulate temperature control valve to maintain discharge air setpoint. When kitchen hoods are operating minimum discharge air setpoint shall be 70 deg. F]
        1. [Hot water coil circulation pump operates whenever main heating system pumps operate.]
    d. [Evaporative Cooling: Enable evaporative cooling whenever there is a call for cooling. When outside air temperatures are below 50 deg. F enable evaporative cooler drain. When outside air temperatures are above 65 deg. F enable evaporative cooler fill.]
    e. Interlock unit to run whenever any kitchen hood exhaust fan runs.
4. Safety Interlocks and Overrides
    a. Smoke Detector: On the detection of smoke from a duct mounted smoke detector, a hard-wired interlock with the supply fan shall shut down the supply fan through a signal to the unit. The unit outside air dampers shall close. The smoke detector shall furnished and wired by electrical and installed by mechanical. The duct mounted smoke detector shall initiate an alarm to the fire alarm system. Coordinate detector requirements with controls contractor, and fire alarm system provider.
    b. Upon activation of the kitchen hood fire system the unit supply air fan shall de-energize and the outside air damper shall close.

5. Monitor and Alarm Points: The value, binary state, setpoint, voltage, run hours, etc. of any input, output, control loop or virtual point shall be monitored on screen. Terminal mode group information screens shall be provided per the standards required by the District.
6. Operator Station Display:
    a. System on/off indication.
    b. System fan on/off indication.
    c. System fan current sensing relay alarm
    d. Fan discharge air temperature indication.
    e. Fan discharge air temperature setpoint/adjustment.
    f. Evaporative cooling system Enable
    g. Evaporative cooling system drain
    h. Evaporative cooling system fill

K. VAV TERMINAL UNIT SEQUENCES OF OPERATION
1. Temperature Setpoints:
    a. Occupied Space Temperature: 75 deg F. cooling, 70 Deg F. heating
    b. Un-Occupied Space Temperature: 85 deg F. cooling, 65 Deg F. heating
    c. Heating Discharge Air Temperature: 90 deg F.
2. VAV Box Operation:
    a. Cooling: Sequence damper from full open to minimum position. HW coil valve is closed.
    b. [Heating: Sequence damper from minimum to maximum heating and concurrently modulate HW coil control valve to maintain space temperature.]
    c. [Heating: Sequence damper from minimum to maximum heating and modulate electric heat states to maintain space temperature.]
3. FPVAV Box Operation:
    a. Fan: Fan is off during occupied periods. Fan is enabled during unoccupied periods.
    b. Occupied Cooling: Sequence damper from full open to minimum position. HW coil valve is closed.
    c. [Occupied Heating: Sequence damper from minimum to maximum heating and concurrently modulate HW coil control valve to maintain discharge air temperature.
    d. [Occupied Heating: Sequence damper from minimum to maximum heating and modulate electric heat states to maintain discharge air temperature.]
    e. [Unoccupied: Cycle fan and modulate HW coil valve to maintain space temperature.]
    f. [Unoccupied: Cycle fan and modulate stages of electric heat to maintain space temperature.]
4. Room CO2 Level Control
    a. During occupied mode, if the CO2 level rises above the space setpoint of [700][xxx] ppm (adj), the air valve (damper) shall slowly increment open as necessary to regain and maintain an allowable CO2 level. If the air valve (damper) when fully open, cannot maintain the proper CO2 level, the air handling unit is notified and shall slowly open its mixing damper to allow additional outside air.
5. Display
    a. System graphic
        1. Occupied/Unoccupied
        2. Space temperature setpoint
        3. Space temperature indication/adjustment
        4. [Control valve position]
        5. [Electric Heat Enable]
        6. Box leaving air temperature
        7. [Space CO2 Level]
        8. [Space CO2 Setpoint]
        9. [Space High CO2 Alarm]

10. [Fan Enable/Disable]
11. [Fan Alarm (from CSR)]

L. CABINET HEATERS
1. Cabinet Unit Heater, Hydronic: Room thermostat cycles fan.
2. Wall mounted thermostat cycles fan and opens control valve when space temperature falls below set point. Pipe mounted Aquastat stops fan when return heating-water space temperature falls below set point.

M. EXHAUST FAN SEQUENCES
1. Refer to mechanical equipment schedules, and drawings for specific fan control methods. Coordinate switched or thermostatically controlled fans with Division 26.
2. Switched Fans: Control by local On-Off switch provided by Division 26. Not a TC function. Provide a 2-position wall switch labeled with 1/2" lettering "Room Exhaust."
3. Line Voltage Thermostat Controlled Fans: Control by local 120-volt thermostat provided by TC. Not a TC function. Provide labeled thermostat with 1/2-inch lettering indicating exhaust fan served.
4. Low Voltage Thermostat Controlled Fans: Control by local low voltage thermostat provided and wired by TC. Provide labeled thermostat with 1/2-inch lettering indicating exhaust fan served.
5. DDC Interlocked Fans: Fans shall be enabled when the associated air handling unit is in occupied mode.
   a. Display and Alarms
      1. System graphic
      2. Fan status/alarm

N. KILN HOOD/KILN INTERLOCK SEQUENCES
1. Interlock kiln exhaust fan to operate whenever any kiln under the hood operates.
2. Provide space temperature sensor to operate exhaust fan whenever space temperature exceeds 85 deg F (adjustable).

O. MISCELLANEOUS POINTS
1. Computer Server Room (IDF Room)
   a. Monitor space Temperature and provide Status of exhaust fan.
2. Crawlspace Sump Pump(s)
   a. DDC system shall monitor sump pump operation/status. Alarm DDC system if pump fails, or upon high water level.
3. DDC Interlocked Dampers:
   a. Dampers shall be opened when the associated air handling unit is in occupied mode.
   b. Display and Alarms
      1. System graphic
      2. Damper position open/closed

END OF SECTION

SECTION 23 21 13

HYDRONIC PIPING AND WATER TREATMENT

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUES
   1. Heating Water Piping
   2. Chilled Water Piping
   3. Condenser Water Piping
   4. Air Elimination System
   5. Chemical Water Treatment

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Standard
      a. ANSI
      b. ASTM
      c. ASME
   2. Minimum Criteria
      a. Quality Assurance: The Water Treatment Company shall be a recognized specialist, active in the field of industrial water treatment, whose major business is in the field of water treatment, and shall have regional water analysis laboratories, development facilities and service department, plus a full-time service representative with a minimum of ten years' experience within in a Denver area. Acceptable Water Treatment Suppliers meeting the above requirements for this project is Mile Hi Water Tech, Inc.
      b. Chemical Water Treatment Maintenance Service:
         1. Provide the services of a fully qualified field engineer and laboratory and technical assistance from a fully qualified laboratory staff for a one (1) year warranty period.
         2. Chemical Stock: Provide sufficient chemicals for treatment and testing during the one (1) year warranty period. Chemicals shall not be harmful to the system in which they are used and shall comply with the Jurisdictional Codes governing the use and discharge of chemical formulations.

C. DESIGN REQUIREMENTS:
   1. Design piping systems with drain valves at main shut-off valves, low points of piping, bases of vertical risers and at equipment.
   2. Design piping systems with isolation valves to isolate each component and branch. Specify and Indicate location of isolation valves for each zone, each riser, all branches, and equipment including coils, air vents and all other hydronic equipment. Valves shall be readily accessible for servicing by maintenance personnel.
   3. Specify diaphragm-type expansion tanks to be used in the system, specify a diaphragm that is compatible with glycol. Plain steel expansion tanks are unacceptable.
   4. Specify flow measuring and balancing device combinations of orifices, venturis, throttling valves and temperature and pressure taps to provide accurate flow measurement for manual balancing of hydronic systems.
   5. For glycol-filled systems, specify that all components exposed to propylene glycol shall be compatible with the specified glycol (especially the seals and gaskets).

D. SUBMITTALS
   1. Product Data:
      a. Air Elimination System
      b. Pipe, Couplings and Fittings
      c. Chemical Water Treatment

2. Operating and Maintenance Data:
    a. Air Elimination System
    b. Chemical Water Treatment

E. RESTRICTIONS/CRITICAL CRITERIA
1. Chemical Water Treatment
    a. Pre-startup Cleaning and Flushing:
        1. The water treatment company shall provide a pre-startup liquid detergent dispersant cleaner for the flushing and cleaning of all closed water systems to remove oil and foreign matter form the piping and equipment prior to the final filling to the systems. This chemical shall not be injurious to person, piping, pipe joint compounds, packaging, coils, valves, pumps, and their mechanical seals, tubes, or other parts of the system.
        2. The water treatment company shall furnish complete instructions dictating the quantities of cleaner to use, methods and duration of operations.
    b. Chemical Feed Equipment for Closed Systems: Five (5) gallon bypass feeders shall be provided with ¾" brass drain valve. All feeders shall be able to withstand a maximum working pressure of 175 PSI.
    c. Condenser Water Systems (Cooling Towers):
        1. Acceptable Manufactures:
            i. Water Treatment Control Systems: Beta Technology, Inc. Omniview Conductivity Controller.
            ii. Water Meter- Carlon
            iii. Chemical Feed Pumps –Neptune N Feeder or LMI-A Series.
        2. Provide an automatic condenser water control system for inhibitor feed and blowdown. Inhibitor application shall be meter activated and blowdown shall be conductivity activated.
        3. Control system shall incorporate solid state integrated circuits and digital LED displays, in a painted steel enclosure. Provide gasketed and lockable door. A prewired, preplumed water sample assembly must be included.
        4. Total dissolved solids control for conductivity to include:
            i. LED digital conductivity readout display (microhm/cm).
            ii. Temperature compensated sensor probe and adaptable to sample stream manifold.
            iii. Two conductivity rangers: 0-2000 mmhos & 0-20000 mmhos.
            iv. Read-set switch for solenoid bleed valve.
            v. Illuminated light shall be indicated "Bleed" when valve is operated.
            vi. Adjustable hysteresis or dead band (internal).
            vii. Flow switch to deactivate feed and bleed when there is no flow.
        5. Inhibitor feed control based on make-up volume to include:
            i. Precision reset time (adjustable 1 to 255 minutes)
            ii. Test switch
            iii. Illuminated light shall indicated "feed" when pump is activated.
        6. Provide a Carlon 5/9" x 3/4" water meter with totalizer on system make-up, wired to control system.
        7. Provide one chemical feed pump to inject chemicals direct from the shipping drum into the condenser water supply to the tower.
        8. Provide a blowdown control assembly of sufficient size including a cast iron pipe strainer with 20 mesh stainless steel screen and solenoid valve.
        9. Provide a PVC piping manifold system to include a flow switch conductivity probe and sample petcock. The manifold system will be attached to the side of the controller, prewired and preplumbed.

d. Open System Water Treatment Chemicals:
    1. Provide an organic phosphorate based scale inhibitor containing molybdate based corrosion inhibitors and silt polymer-based dispersants. The treatment shall be in liquid form and be suitable for feeding into the system directly from the shipping container. This chemical treatment shall not contain chromate or phosphate. Acid for PH control not allowed.
    2. Provide liquid biocides of two chemically different types of formulation to be used on an alternating basis and to be effective against all normally encountered algae and slime growths. Biocides must be EPA approved.
    3. Provide chemical pump for algaecides.
    4. Provide full secondary containment pallet for all chemicals.
    5. Provide a fully functioning eyewash / shower station in close proximity to chemical storage, feed pumps and controller similar to Grainger product 34A699.
e. Water Treatment Control Testing Equipment:
    1. Provide testing chemicals to properly analyze the condenser water for organic phosphonate and closed system water for nitrite. Furnish the necessary test kits for these tests.
    2. Provide a Myron-L TDS meter, 3-range, 0-50, 0-500, 0-5000 mmhos/cm auto-temp compensation 50-160° F, 9-volt transistor batteries and built in cell.
    3. Furnish a supply of log sheets to record the test results and a bound copy of full test instructions.

2. Freeze Protection:
    a. Chilled and Heating Water Systems (for systems exposed to outdoors): Provide 30% Propylene Glycol with inhibitors.
    b. Provide a fully functioning eyewash / shower station in close proximity to chemical storage, feed pumps and controller similar to Grainger product 34A699.
3. Pipe Sizing:
    a. Chilled water, condenser water and heating water piping: Size pipe not to exceed a velocity of 6 feet per second and a maximum water pressure drop of 4 feet per 100 feet. Flow rates shall be based upon total connected load without diversity.

PART 2 – PRODUCTS

A. HEATING WATER, CONDENSER WATER AND CHILLED WATER PIPING
    1. Accessible Above Grade:
        a. 2” and smaller:
            1. Pipe: ASTM A53, Grade B, Schedule 40, Black Steel.
            2. Joints: Screwed.
            3. Fittings: ANSI/ASTM A126, 125 lb. cast iron or ANSI/ASTM A197, 150 lb. malleable iron.
            4. Unions: 250 lb. black malleable iron, ground joint with brass seat. Use dielectric unions to connect copper to steel piping.
            5. Copper tubing ASTM B88, Type L, hand drawn with ANSI/ASME B16.23 cast brass and/or ANSI/ASME B16.23 cast brass and/or ANSI/ASME B16.29 solder wrought copper may be used in lieu of steel pipe for size 1 ½” and smaller. Solder shall be no-lead type.
        b. 2 ½“ and larger:
            1. Pipe: ASTM A53, Grade B, Schedule 40, Black Steel.
            2. Joints: Welded.
            3. Fittings: ANSI/ASTM A234, Grade WPB, Schedule 40, seamless steel, butt weld type.
            4. Flanges: ASTM A181, Grade B, regular square head machine bolts with heavy hexagonal nuts to be used at equipment or valve connections only.

    2. Inaccessible Above Grade: Same as for 2 ½” and larger, accessible above grade.

3. Below Grade: Same as for 2 ½” and larger, except welded fittings. Provide bituminous pipe coating, minimum thickness 1 mil for all underground pipe.

B. AIR ELIMINATION SYSTEM
   1. Acceptable Manufactures:
      a. Bell and Gossett
      b. Amtrol
      c. Taco
      d. Wessels
   2. Expansion Tank: Pre-charged steel expansion tank with replaceable heavy duty butyl rubber bladder. The tank shall have a 1 ½" NPT system connection, 3/4" NPT drain and a .032"-32 charging valve connection (standard tire valve) to facilitate the on-site charging of the tank to meet system requirements. The tank must be constructed in accordance with Section VIII of ASME Boiler and Pressure Vessel Code and stamped 125 PSI working pressure.
   3. Air Separator: Cast iron or welded steel constructed, tested and stamped in accordance with Section VIII of the ASME Code for working pressure of 125 PSI. Provide integral strainer with air separator.
   4. Air Eliminator: Valve constructed of metal and non-corrosive working parts. Working pressure shall be 150 PSI. Coin operated or screw top air vents are not acceptable.
      a. Air: Eliminated to the atmosphere as fast as it is separated from system water through a float activated, remote pressure operated air elimination valve installed at the tip of the air separator.
      b. Air Elimination Valve: High removal rate at low pressure differentials and fully open for the removal of air at pressures in the operating range from 2 PSI to 150 PSI. Capacity shall not be less than 17 SCFM at 30 PSI.
      c. Valve: Tightly sealed against loss of system water and prevent entrance of air in negative pressure situations.

END OF SECTION

SECTION 23 21 23

HVAC PUMPS

PART 1- GENERAL

A. SUMMARY- SECTON INCLUDES
   1. Pumps

B. REFERENCED STANDARDS- MINIMUM CRITERIA
   1. HI- Hydraulic Institute, Standard for Centrifugal Pumps
   2. ASRM- American Society for Testing and Materials
   3. NEC- National Electric Code

C. SUBMITTALS
   1. Product Data: Pumps (HVAC)
   2. Operating and Maintenance Data: Pumps (HVAC)

D. RESTRICTIONS/CRITICAL CRITERIA
   1. General:
      a. Statically and dynamically balanced rotating parts.
      b. Construction: Permit complete servicing without breaking piping or motor connections.
      c. Pumps operate at 1750 RPM unless specified otherwise.
      d. Pump connection: Flanged.
      e. Pump manufacturer to check suction condition on pumps and provide pumps suitable for operation at proper net positive suction head (NPSH).
      f. Motor to be non-overloading at job site altitude (not exceed nameplate amperage) throughout the range of the pump curve. Motor shall be high efficiency. Refer Section 23 000 04 for additional requirements.
      g. Each pump shall be factory tested for the specified operating conditions. It shall then be thoroughly cleaned and painted with at least one (1) coat of high-grade machinery enamel prior to shipment.
      h. Pump shall be selected at or near maximum efficiency and shall not utilize impeller size more than 85% of the cut-water radius or smallest impeller available. Pump curves for all base mounted and horizontal close coupled circulating pumps shall not droop near shut- off.
      i. Impellers shall be bronze.
      j. Minimum of 70% efficiency at the design point for pumps larger than 3 HP.
      k. Install pumps to allow complete removal without dismantling connecting piping.
      l. Provide air cock and drain connection on horizontal pump casting.
      m. Provide flexible pipe connections for all base mounted pumps.
   2. Select pump motor as non-overloading over the entire pump curve shown by the manufacturer. Select pump based on operating temperatures and fluid types.
   3. Coil circulation pumps and system circulation pumps shall not be located above ceilings. Locate pumps where accessible in equipment rooms or within air handling equipment if located on roof.

PART 2- PRODUCTS

A. PUMPS
   1. Acceptable Manufacturers
      a. Pumps 3/4 HP and greater:
         1. Bell and Gossett

2. Paco
3. TACO

b. Pumps less than 3/4 HP:
1. Paco
2. TACO
3. Bell and Gossett

B. BASE-MOUNTED PUMPS
1. General Pump Requirements
a. Pump Units: Factory assembled and tested.
b. Motors: Include built-in, thermal-overload protection and grease-lubricated ball bearings. Select each motor to be non-overloading over full range of pump performance curve. If variable speed drives are used, provide inverter duty motors.
c. Motors Indicated to Be Energy Efficient: minimum efficiency as indicated according to IEEE 112, Test Method B. Include motors with higher efficiency than "average standard industry motors" according to IEEE 112, Test Method B, if efficiency is not indicated.
2. Flexible-Coupled, End-Suction Pumps
a. Description: base-mounted, centrifugal, flexible-coupled, end-suction, single-stage, bronze-fitted, back-pull-out, radially split case design; rated for 175-psig minimum working pressure and a continuous water temperature of 225 deg F.
1. Casing: cast iron, with flanged piping connections, drain plug at low point of volute, threaded gage tapping's at inlet and outlet connections, and integral feet or other means on volute to support weight of casing and attached piping. Casing shall allow removal and replacement of impeller without disconnecting piping.
2. Impeller: ASTM B 584, cast bronze, statically and dynamically balanced, closed, overhung, single suction, keyed to shaft, and secured by locking cap screw.
3. Wear Rings: replaceable, bronze casing ring.
4. Shaft and Sleeve: steel shaft with bronze sleeve.
5. Seals: mechanical, with carbon-steel rotating ring, stainless-steel spring, ceramic seat, and flexible bellows and gasket.
6. Seals: stuffing box, with at least four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.
7. Coupling: flexible, capable of absorbing torsional vibration and shaft misalignment.
8. Coupling Guard: steel, removable, and attached to mounting frame.
9. Mounting Frame: welded-steel frame and cross members, factory fabricated from ASTM A 36/A 36M channels and angles. Fabricate for mounting pump casing, coupling guard, and motor. Field-drill motor-mounting holes for field-installed motors.
10. Motor: secured to mounting frame, with adjustable alignment.

C. IN-LINE PUMPS
1. Description: Horizontal, in-line, centrifugal, single-stage, bronze-fitted, radially split case design; rated for 125-psig minimum working pressure and a continuous water temperature of 225 deg F.
2. In-line pumps used for coil circulation shall include drain pan below pump. Drain pan shall include full size of pump and be drained to exterior or nearest floor drain/floor sink.

D. PUMP SPECIALTY FITTINGS
1. Suction Diffuser: angle or straight pattern, 175-psig pressure rating, cast-iron body and end cap, pump-inlet fitting; with bronze startup and bronze or stainless-steel permanent strainers;

bronze or stainless-steel straightening vanes; drain plug; and factory- or field-fabricated support.

2. Triple-Duty Valve: angle or straight pattern, 175-psig pressure rating, cast-iron body, pump-discharge fitting; with drain plug and bronze-fitted shutoff, balancing, and check valve features.

END OF SECTION

SECTION 23 23 00

HVAC REFRIGERANT PIPING

PART 1- GENERAL

A. SUMMARY- SECTION INCLUDES
    1. Refrigerant Piping and Fittings

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
    1. ASTM
    2. ANSI

C. SUBMITTALS
    1. Provide letter of guarantee of performance of A/C system to Owner.

D. RESTRICTIONS/CRITICAL CRITERIA
    1. Testing: All piping lines shall be pressurized with a 90% nitrogen, 10% refrigerant mixture to the design working pressure of the piping (i.e. discharge and liquid 400 PSI, suction 150 PSI). The test charge, with pressure gauges attached, shall be left for a period of twenty-four (24) hours. At the end of this period, regardless of whether a pressure drop is noted or not, a thorough leak search shall be performed on all piping joints including heat transfer coils.
    2. Specify environmentally friendly refrigerants. Specify R-410A or R-134A as preferred, R-123 is acceptable although not recommended.
    3. Specify refrigerant piping accessories as required for specific refrigeration equipment including:
        a. Filter dryer for liquid line of adequate size, replaceable if available.
        b. Sight glass moisture indicator installed in the liquid line at a convenient and accessible location.
        c. Liquid solenoid valve located near the expansion valve on systems using coil pump-down.
        d. Service hand valves shall be required on small and extensive or large refrigerant systems. They shall be located for component isolation purposes during normal maintenance.
        e. Liquid charging port and service valve installed in the liquid line on large systems.
        f. Oil separators required if evaporator is below 0^{o}F and located below condensing unit.
        g. Oil traps to be installed if the vertical rise of refrigerant piping exceeds 8 feet.

PART 2- PRODUCTS

A. GENERAL
    1. Piping: Conforms with ASTM B-280 and ANSI B31.5.
        a. Type L, ACR hard drawn lengths.
        b. Soft annealed bendable lengths or coils.
    2. Fittings: As manufactured by Mueller Brass Streamline Series
        a. Wrought copper, refrigerant grade.
        b. Fittings shall be long radius.
        c. SAE forged brass flare fittings.

END OF SECTION

SECTION 23 30 00

FIRE AND SMOKE DAMPERS

PART 1- GENERAL

A. SUMMARY- SECTION INCLUDES
   1. Fire and Smoke Dampers

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Regulatory Requirements: Comply with the following standards:
      a. NFPA 90A
      b. NFPA 90B
      c. UL Standard UL 555 and UL 555S
      d. SMACNA Fire Damper and Heat Stop Guide for Air Handling Systems.

C. SUBMITTALS
   1. Shop Drawings and Product Data: Fire Dampers, Smoke Dampers and Combination Fire/Smoke Dampers.

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Installation shall be in accordance with UL listing, SMACNA's Fire Damper Guide and damper manufacturer recommendations.
   2. Dampers shall be accessible for inspection or resetting through removable diffuser or register or access doors provided for the purpose. Location of access doors, when above ceilings, shall be marked FD or SD, F/SD, as appropriate.
   3. Provide dampers in duct work at ceiling, wall and floor penetrations as required by building codes.

PART 2- PRODUCTS

A. FIRE DAMPERS
   1. Acceptable Manufacturers:

      a. National Controlled Air
      b. Greenheck
      c. Air Balance
      d. Prefco
      e. Vent Products
      f. Nailor
      g. United Air
   2. Specify that fire dampers shall be constructed, tested, and labeled in accordance with UL555S Standard and shall also be in compliance with NFPA 90A.
   3. Specify that fire dampers shall be installed in accordance with their UL listing, NFPA 90A, and the manufacturer's installation instructions.

B. SMOKE AND COMBINATION FIRE/SMOKE DAMPERS
   1. Acceptable Manufactures:
      a. National Controlled Air
      b. Greenheck
      c. Nailor
      d. United Air

e. Prefco
f. Air Balance

2. Combination fire/smoke dampers shall be constructed, tested, and labeled in accordance with UL555/UL555S Standards and shall also be in compliance with NFPA 90A.
3. Combination fire/smoke dampers shall be installed in accordance with their UL listing, NFPA 90A, and the manufacturer's installation instructions.
4. Smoke dampers shall be constructed, tested, and labeled in accordance with UL555S Standard and shall also be in compliance with NFPA 90A.
5. Smoke dampers shall be installed in accordance with their UL listing, NFPA 90A, and the manufacturer's installation instructions.
6. Provide with electric (120V, 1Ø) operators in the buildings.

.END OF SECTION

SECTION 23 31 13

LOW PRESSURE SHEET METAL DUCTWORK

PART 1- GENERAL

A. SUMMARY- SECTION INCLUDES
   1. Ductwork, Sealer and Accessories
   2. Ductwork Testing

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Regulatory Requirements: Comply with the following standards:
      a. NFPA 90A-2002: Air Conditioning and Ventilating Systems
      b. NFPA 90B-2002: Warm Air Heating and Air Conditioning Systems
      c. UL 181: Factory-Made Duct Materials and Air Duct Connections
      d. ASHRAE Handbook: Sheet Metal Design Standards
      e. SMACNA HVAC Duct Construction Standards, 2005 Edition with Supplements

C. SUBMITTALS
   1. Shop Drawings and Product Date:
      a. Low Pressure Ductwork, Flexible Connectors and Spin-In Fittings
      b. Low Pressure Flexible Ductwork
      c. Air Distribution Accessories

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Fiberglass ductwork not allowed except for return air sound boots and transfer air ducts.

PART 2- PRODUCTS

A. DUCTWORK
   1. General: Fabricate in accordance with referenced SMACNA HVAC Duct Construction Standards and ASHRAE Handbook. Use when subjected to total static pressures blew 2” WG. Duct gauges shall be as listed in Table 1-1 and Seal Class B, refer SMACNA manual. Rigid ductwork shall be constructed of “lock forming” quality galvanized steel. Exposed rectangular ductwork in Gymnasium to be 16 gauge.
   2. Hangers: Provide in accordance with referenced SMACNA Standards.
   3. Access Doors: Install hinged doors on ductwork and housing to provide access to parts of every automatic damper, fire damper, combination fire/smoke damper, duct coil, in-duct thermostat and other items requiring maintenance or inspection. Access doors shall be 24” x 24” minimum if permitted by duct size, and of not, shall be as large as possible. Access panels shall be at least two (2) gauges heavier than the surface in which place and shall be constructed as shown in Fig. 2-12 in SMACNA HVAC Duct Construction Standards.
   4. Provide airfoil turning vanes for all supply and return ductwork. Provide airfoil turning vanes for all outside air and relief air ductwork which include fan as means of providing outside air or relief air.

B. FLEX DUCT
   1. Approved Manufacturers:
      a. Flexmaster
      b. Hart & Cooley
      c. Thermoflex
      d. Wiremold
      e. Hercules

2. Insulated Flexmaster Type 5M: Branch duct connections to trunk duct shall be sheet metal spin-in type with integral damper and 45-degree extractor. Maximum length of flex duct shall not exceed 5 ft.

C. DUCTWORK- ALUMINUM
   1. All ductwork associated with the following systems shall be stainless steel, of B &S gauge conforming to appropriate ASHRAE Handbook (latest edition) with sealed joints. ANSI/ASTM B209; aluminum sheet, alloy 3003-H14. Aluminum Connectors and Bar Stock: Alloy 6061-T6 or of equivalent strength
      a. Dishwasher exhaust system.

D. DUCTWORK- WELDED STEEL
   1. All ductwork associated with the following systems to be 16 gauge welded black steel:
      a. Kitchen hood exhaust system
      b. Specify duct access doors for all grease exhaust duct per International Mechanical Code.

E. AIR DISTRIBUTION ACCESSORIES
   1. General:
      a. Provide all necessary air distribution system accessories to assure proper balance, quiet and draft less distribution and conveyance, minimization of turbulence, noise and pressure drop for all supply air qualities indicated.
      b. Products shall be recommended by the manufacturer for the application.
   2. Remote Operators: Provide Young Regulators Company remote damper operators where required for operation of dampers, splitter, extractors, etc.
   3. Control Grids: Provide control grids at entrance to all square or rectangular ceiling diffusers with square neck and side wall registers located at the end of branch run and distance from grid to diffuser or register face is 2’-0” or less. When distance exceeds 2’-0”, and extractor shall be used.
   4. Volume Dampers: Construction: Volume damper frame shall be minimum 16-gauge galvanized steel. Blades shall be minimum 16-gauge galvanized steel, reinforced with 3 longitudinal structurally design vees. Linkage side assembly shall be concealed in frame located out of air stream. Bearing shall be synthetic sleeve type. Axles shall be ½” diameter plated steel with removable control shaft which extends 6” beyond frame.

F. GYMNASIUM/EXPOSED DUCTWORK
   1. Exposed Round Ductwork: Duct and fittings shall be equal to United Sheet Metal galvanized steel, meeting ASTM A-527-71. Duct shall be fabricated as spiral uniseal through 20” minor axis with longitudinal seam duct for minor axis of 22” or longer. All fittings shall be continuous weld. Exposed ductwork in Gymnasium to be 16 gauge.
      a. Exposed ductwork shall be paintlock type as required by architect for painting of ductwork in exposed areas.

G. OUTDOOR AIR LOUVERS AND HOODS
   1. For OA Intake Louvers: Provide plenum full size of intake louver, minimum 24” deep. Bottom of plenum shall be sealed liquid tight and slope to a 1” copper condensate drain. Extend condensate line to nearest floor drain.
   2. For OA Roof Mounted Intake Hoods: OA duct to be sealed liquid tight. At first horizontal offset provide 1” copper condensate drain. Bottom of horizontal offset provide 1” copper condensate drain. Bottom of horizontal duct shall be sealed liquid tight and sloped to condensate drain. Extend condensate line to nearest floor drain. Remainder of duct does not have to be sealed liquid tight.

END OF SECTION

SECTION 23 31 14

MEDIUM PRESSURE SHEET METAL DUCTWORK

PART 1- GENERAL

A. SUMMARY

1. Ductwork, Sealer and Accessories
2. Ductwork Testing

B. REFERENCED STANDARDS (MINIMUM CRITERIA)

1. Regulatory Requirements: Comply with the following standards:
   a. NFPA 90A: Air Conditioning and Ventilating Systems
   b. NFPA 90B: Warm Air Heating and Air Conditioning Systems
   c. UL 181: Factory-Made Duct Materials and Air Duct Connections
   d. ASHRAE Handbook: Sheet Metal Design Standards
   e. SMACNA HVAC Duct Construction Standards

C. SUBMITTALS

1. Shop Drawings and Product Data:
   a. Medium Pressure Ductwork: Spiral pipe, fittings, perforated metal liner, joint sealer and tape.
   b. Medium Pressure Flexible Ductwork

D. RESTRICTIONS/CRITICAL CRITERIA

1. General: The execution of the work shall be in strict accordance with the best practices of the trade and with these Specifications. All sheet metal ductwork shall be constructed in accordance with the current edition of the HVAC Duct Construction Standards published by the Sheet Metal and Air Conditioning Contractor National Association, Inc. (SMACNA).
2. Rectangular Ductwork: Duct gauges for rectangular ductwork shall be as listed in table 1-7 for 4” WG. Static positive seal class (A) of the SMACNA HVAC Duct Construction Standards. Duct to be constructed to higher static if system design requires more than 4” WG. Engineer shall consult with School District if system design requires static pressure greater than 4” WC.
3. Round and Oval Ductwork: The assembly and installation of pre-manufactured round and oval ductwork shall be in accordance with duct manufacturer’s recommendations. Provide adhesive on inside and outside of joints and tape and brush tape with sealer.
4. Medium pressure ductwork shall be tested in accordance with SMACNA recommendations.

PART 2- PRODUCTS

A. DUCTWORK

1. General: Fabricate all rectangular ductwork in accordance with referenced SMACNA HVAC Duct Construction Standard. All round ductwork and fittings shall be manufactured by a company who has as its principal business the manufacture of spiral pipe and welding fittings. The same firm shall manufacture the Ductwork and fittings to assure tight fit of all ductwork and components.
2. Oval and round ductwork: Duct and fittings shall be galvanized steel, meeting ASTM A-527-71. Duct shall be fabricated as spiral uniseal through 20” minor axis with longitudinal seam duct for minor axis of 22” or larger. All fittings shall be continuous weld. All take-offs shall be conical unless otherwise indicated. All ductwork which has conical take-offs and fittings shall be fabricated in accordance with ASTM A527-71. All take-offs shall be full body taps, saddles type taps not allowed.

a. Acceptable Manufactures:
    1. Hercules Industries
    2. LaPine Metal Products
    3. Spiral Pipe of Texas
3. Joint Sealing
    a. The sealing and duct slip joint and fitting connections of duct fittings shall be accomplished with UL listed sealer, sheet metal screws and sealing tape. Tape and sealer shall be compatible materials and designed for sealing medium/high pressure duct systems. Sealers shall be United Duct Sealer and Hardcast, Inc. RTA-50 adhesive.
    b. Flanged joints shall be sealed by Neoprene rubber gaskets.
    c. Round spin-in fitting connecting to rectangular duct shall be spun-in, locked in place with sheet metal screws and sealed.
4. Flexible connection at equipment shall be accordance with the requirements of MFPA 90A. Material shall be glass fabric coated on the exterior (not air side) with a fire-retardant compound. Duradynes “Excelon” or equal, with UL label. It shall be suitable for pressure encountered.

B. HANGERS
1. Provide in accordance with referenced SMACNA Standards.

C. ACCESS DOORS
1. Install hinged doors on ductwork and housing to provide access to parts of every automatic damper, fire damper, combination fire/smoke damper and other items requiring maintenance or inspection. Access doors shall be 24” x 24” minimum if permitted by duct size, and if not, shall be as large as possible. Access panels shall be at least two (2) gauges heavier than the surface in which placed and shall have sponge rubber gasket cemented in place.

D. FLEX DUCT
1. Approved Manufacturers:
    a. Flexmaster
    b. Wiremold
    c. Hart & Cooley
    d. Thermoflex
    e. Hercules
2. Insulated Flexmaster Type 3M insulated Type SLR-181: Branch duct connections to trunk duct shall be sheet metal spin-in conical type, equal to Flexmaster Series 3000S Model CB. Flex duct shall only be used to connect medium pressure SA duct to fan powered VAV terminal units. Maximum length of flex shall not exceed 6 ft.

END OF SECTION

SECTION 23 34 16

EXHAUST FANS

PART 1- GENERAL

A. SUMMARY- SECTION INCLUDES
   1. Exhaust Fans

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. AMCA

C. SUBMITTALS
   1. Product Data:
      a. Exhaust Fans
   2. Operating and Maintenance Data:
      a. Exhaust Fans

D. DESIGN REQUIREMENTS
   1. Specify direct drive fans for all fans 1/2hp and smaller. Specify belt drive fans for fans over 3/4hp.
   2. Centrifugal, tubular centrifugal, axial and propeller fans may be used. The use of propeller fans shall be kept to a minimum. The District shall approve the use of propeller type exhaust fans. Propeller fans shall include sound requirements for approval by the Engineer.
   3. All fan motors shall comply with 23 00 04 Motors and Drives
   4. Utility Set Fans:
      a. When only design solution requires exposure to weather, specify weather covers with quick release fasteners for ease of access to belts and bearings.
      b. Greaseable bearings for all accessible fans. Zerks shall be located outside of fan housing and extended where otherwise difficult to access.
   5. Specify vibration isolation devices for all utility set and hung cabinet fans. Vibration isolation shall minimize transmitted vibration to building structure. Refer to section 23 05 48.

PART 2- PRODUCTS

A. EXHAUST FANS
   1. Acceptable Manufacturers:
      a. Greenheck
      b. Acme
      c. Penn
      d. Loren Cook
      e. Carnes
      f. Twin City Fans
   2. Type, Capacity and Size: As indicated on drawings.
   3. General: Provide fans with statically and dynamically balanced wheels, free from objectionable vibrations. Capacities to be AMCA certified. Provide fans with permanently lubricated ball bearing motors located in separate compartment out of the airstream, factory roof curbs where required and back draft dampers.

B. ROOF FANS
   1. Housing: All aluminum venture inlet, bird screen.
   2. Wheel: (Type as indicated by model number).
      a. Centrifugal: Aluminum backward-inclined, balanced.
   3. Drive: (Type as indicated by model number).

a. Direct: Wheel keyed to shaft. Provide solid state speed controller or ECM motor to fan to allow for balancing of direct drive motors.
b. Belt: Adjustable sheaves, ball-type shaft bearings greased for operation to -10°F. Automatic belt tensioner or idler pulley systems are not approved for belt driven fans.

4. Motors: Ball bearings greased for operation to -10°F, out of primary air steam, built-in overload where scheduled, electrical disconnect.
5. Roof Club:
   a. Standard curb: Factory-built, 16" high (minimum), internally insulated, self-flashing roof curb. Curb height shall be sufficient enough to allow for fan cap to be a minimum of 12" above top of roofing.
   b. Sound attenuating curb: Factory-built, 16" high, internally insulated, self-flashing roof curb, heavy gauge galvanized steel with continuous welded water-tight corners. Rated at 40% fan sone reduction without appreciable air pressure drop. Sound baffles shall be vertical type, horizontal center baffle type not acceptable. Curb height shall be sufficient enough to allow for fan cap to be a minimum of 12" above top of roofing.
6. Accessories: Gravity back-draft damper (unless scheduled otherwise), miscellaneous items as scheduled.

C. CEILING AND IN-LINE CABINET FANS
1. Sound-insulated housing with back-draft damper, resiliently mounted direct-drive motor, centrifugal wheel, electrical disconnect, access to removable internals, inlet grille (ceiling fans), accessories as scheduled. Provide solid state speed controller or ECM motor to fan to allow for balancing of direct drive motors.

D. PROPELLER FAN
1. Housing: Steel panel with steel tubing supports pre-drilled fan panel with all parts except for wheel are furnished in baked enamel prior to assembly.
2. Blades: Variable pitch, five-bladed cast aluminum wheel, balanced.
3. Drive: Adjustable belt drive with belt guards.
4. Motors: Open drip-proof, ball bearings greased for operation to minus 10oF, built-in overload where scheduled.
5. Accessories: Heavy duty safety box guard to meet OSHA safety requirements and gravity operated damper.

E. UTILITY SET FANS
1. Description: belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and accessories.
2. Housing: fabricated of steel with side sheets fully welded to scroll sheets.
   a. Housing Discharge Arrangement: adjustable to eight standard positions.
3. Fan Shaft: turned, ground, and polished steel; keyed to wheel hub.
4. Shaft Bearings: prelubricated and sealed, self-aligning, pillow-block-type ball bearings with ABMA 9, L_{50} of 200,000 hours.
5. Belt Drives: factory mounted, with final alignment and belt adjustment made after installation.
   a. Service Factor Based on Fan Motor: 1.5
   b. Motor Pulleys: adjustable pitch for use with motors through 5 hp; fixed pitch for use with motors larger than 5 hp. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   c. Belts: oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   d. Belt Guards: fabricate of steel for motors mounted on outside of fan cabinet.
   e. Utility set fans located on roof shall include mounting platform complete with vibration isolation between fan and platform.

END OF SECTION

SECTION 23 36 00

VARIABLE AIR VOLUME TERMINAL UNITS

PART 1- GENERAL

A. SUMMARY-SECTION INCLUDES
   1. VAV Terminal Units

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. ARI
   2. NFPA

C. SUBMITTALS
   1. Shop Drawings and Product Data
      a. VAV Terminal Units- Cooling with reheat.
      b. VAV Terminal Units- Fan Powered
   2. Operating and Maintenance Data:
      a. VAV Terminal Units- Cooling with reheat.
      b. VAV Terminal Units- Fan Powered

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Installation
      a. Coordinate location with all ducts, beams, lights, piping, air distribution devices and other items in immediate vicinity of indicated locations. Make minor adjustments in exact locations shown to best fit available space.
      b. Make all duct connections to and from boxes in as streamlined a manner as practical so that air pressure drop is minimized. Make such connections air tight at operating pressures encountered.
      c. Locate terminals so that access for repair, maintenance and adjustment is easily facilitated without removal of other permanently located items which are in the immediate vicinity of terminals (this excludes removable ceiling panels, removable air distribution devices attached to flexible ductwork and other similar items).
   2. Fan Powered Terminal Units
      a. Due to maintenance concerns the use of fan powered terminals is restricted. Fan powered terminal units are allowed in Kindergarten Classrooms only. In the event the Engineer desires to use units in other locations he shall consult with the School District.
   3. VAV Terminal Unit Sizing
      a. The maximum total air pressure drop through the VAV Terminal Unit (includes air valve, housing, HW coil) shall not exceed 0.50” WG at nominal air valve CFM scheduled. Provide APD data in submittals.

PART 2- PRODUCTS

A. VAV TERMINAL UNITS
   1. Acceptable Manufacturers:
      a. Envirotec
      b. Carnes
      c. Metal Aire
      d. Titus
      e. Price Industries
   2. Model and Capacities: As indicated on drawings.
   3. Cooling with Reheat:

a. Performance: ARI shall certify all performance.
b. Options: Hot water coils shall come factory mounted on the discharge of the terminal unit casing with the capacity as shown on the schedule. Coil shall be constructed of aluminum fins with spacer collars to maintain uniform spacing. Fins shall be mechanically affixed to copper tubes insuring maximum heat transfer. All coils shall be tested to 400 PSIG. Right- or left-hand connections shall be as indicated on equipment drawings.

4. Fan Powered Series Type:
   a. Construction:
      1. Unit fan assembly shall be dynamically balanced, epoxy coated, forwardly curved, direct drive wheel.
      2. Blower motor shall be high efficiency, permanently lubricated sleeve bearing, . Name-plate full load amps must vary by tap. A three-tap motor switch shall be unit mounted and wired to preclude field wiring. Motor shall be suitable for 120V, 277V, or 208V single phase power. Single speed, single tap motors are not acceptable. In addition, an electronic speed controller or ECM motor shall be provided to fine balance the fan to specified CFM. Fan controller shall include a voltage limiting circuit to protect motor from stalling and eventual damage due to low RPM operation.
   b. Performance: All performance shall be tested in accordance with ARI 880.
   c. Options:
      1. Hot water coils shall be factory mounted on the discharge of the terminal unit casing with the capacity as shown on the schedule. Coil shall be constructed of aluminum fins with die-formed spacer collars to maintain uniform spacing. Copper tubes mechanically expanded into the fins. All coils shall be tested to 400 PSIG. Right- or left-hand connections shall be as indicated on equipment drawings.
      2. Attenuator: Fan powered terminal units shall be furnished with plenum inlet sound attenuator constructed of 22-gauge galvanized steel, lined with 1 inch glass fiber insulation. Insulation shall be UL listed and meet NFPA 90A and UL 181 requirements.
5. Temperature Control Contractor to provide DDC terminal controllers and damper actuators to terminal unit manufacturer with complete mounting and wiring instructions and demonstrations for factory mounting and wiring including power transformer. Terminal unit manufacture to include cost of mounting controls. Refer Section 23 09 00 for Temperature Control Contractor.

END OF SECTION

SECTION 23 37 13

AIR DISTRIBUTION

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Diffusers, Grilles, and Registers
   2. Louvers
   3. Intake and Relief Hoods

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Regulatory Requirements: Comply with the following standards:
      a. NFPA 90A-2002: Air Conditioning and Ventilating Systems
      b. NFPA 90B-2002: Warm Air Heating and Air Conditioning System

C. SUBMITTALS
   1. Shop Drawings and Product Data:
      a. Diffusers, Grilles, and Registers
      b. Louvers
      c. Intake and Relief Hoods

D. RESITRICTIONS/CRITICAL CRITERIA
   1. Provide safety chains for all FRD's located in Gymnasiums.
   2. Intake and relief hoods shall have extended necks and internal 1" thick insulation on underside of hood. Roof curb to be minimum 14" high.
   3. Seal ductwork and provide condensate drain lines for intake louvers and intake hoods. Refer Section 23 31 13.

E. INTAKE AND RELIEF
   1. Design outside air intakes protected from prevailing winds.
   2. Size intake louvers to prevent the infiltration of snow and rain. Do not exceed manufacturer's recommended inlet velocities.
   3. Locate intake hoods a minimum of 30 feet from plumbing vents and exhaust outlets. Locate relief vents a minimum of 20 feet from operable windows.

PART 2 – PRODUCTS

A. DIFFUSERS, GRILLES, AND REGISTERS
   1. Acceptable Manufacturers:
      a. Titus
      b. Metal Aire
      c. Price Industries
      d. Manufacturer, Sizes and Finishes: As indicated on drawings.
   2. Ceiling Diffusers:
      a. Rectangular/square louvered face type.
   3. Ceiling Registers and Grilles:
      a. Ceiling supply registers and grilles shall be adjustable curved blades, double deflection type.
   4. Ceiling Return and Exhaust Grilles/Registers:
      a. Square or rectangular curved blades or eggcrate type.
      b. Exhaust and return registers shall include integral volume damper.

5. Sidewall Supply Registers:
    a. Heavy duty type with integral volume damper and 2-way throw.
    b. Registers shall include tamper-proof hardware.
6. Sidewall Return/Exhaust Registers:
    a. Heavy duty type with integral volume damper and 2-way throw.
    b. Registers shall include tamper-proof hardware.

B. LOUVERS
1. Acceptable Manufacturers
    a. Greenheck
    b. Loren Cook
    c. Acme
2. Furnished and installed by Mechanical Contractor.
3. Louvers shall be drainable and have aluminum bird screen.

C. INTAKE AND RELIEF HOODS
1. Acceptable Manufacturers:
    a. Greenheck
    b. Loren Cook
    c. Acme
2. Intake and Relief hoods shall include backdraft dampers. Motorized dampers for relief air hoods and include building pressurization control. Intake dampers are recommended to be two position motorized type.
3. Intake and relief hoods shall be mounted on 24” minimum curb, with hinged hood cap for access to dampers.
4. Intake and Relief hoods over 48” square shall include 12”x12” minimum weatherproof access door for inspection of backdraft damper. Hoods over 60” square shall include 24”x24” weatherproof access door for inspection and maintenance on backdraft damper without removal of hood.

END OF SECTION

SECTION 23 52 23

NON-CONDENSING BOILERS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Boilers with Burner Units

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Comply with the applicable sections of the ASME Boiler Code.
   2. Install boilers in accordance with the manufacturer's installation instructions and requirements of International Fuel Gas Code and CSD-1 requirements. Complete work in a neat and workmanlike manner.

C. SUBMITTALS
   1. Shop Drawings and Product Data:
      a. Boilers and Burners
   2. Operation and Maintenance Data:
      a. Boilers and Burners

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Install boilers and surrounding piping and appurtenances so components requiring service are easily accessible and removable.
   2. Provide System Startup, refer Section 23 05 97.
   3. Provide Demonstrations, refer Section 23 05 97.
   4. The use of non-condensing boiler systems shall be limited to the replacement of existing boiler plants where condensing boiler plants are not feasible. Coordinate with the District for current operating limits and requirements for the existing boiler plant to determine if condensing boilers are feasible, or if non-condensing boiler plants are required.
   5. Non-condensing boiler plants shall include fire-tube, water-tube, and cast-iron boilers.
   6. Specify supply and return water temperatures which will not cause damage to boilers. Specify boiler circulation pumps. Refer to 23 09 00 for boiler control requirements.
   7. The design engineer shall be responsible for field verifying all existing conditions associated with the boiler replacement. Field verification shall include, but not be limited to, combustion air system, make-up air systems, control system and distribution system. Verify all components are operating properly for the new design. Engineers shall specify the repairs required to make the systems operational.
   8. Engineer shall verify the existing heating system in the boiler room. If the room is being heated by the boiler heat loss, the engineer shall design a new supplemental heating system. The system shall be capable of heating the room to a minimum of 50°F at all times. The engineer shall be responsible for specifying the requirements for freeze protection of all of the lines within the boiler room. Specify motorized dampers for combustion air ducts for freeze protection. Specify interlock with dampers to operate/open whenever any boiler or water heater operates.
   9. Provide an emergency shutoff switch (EPO) at entry into boiler room if not already present.

PART 2 – PRODUCTS

A. BOILERS
   1. Acceptable Boiler Manufacturers:
      a. Weil-McLain
      b. Buderus
      c. HB Smith

2. Acceptable Burner Manufacturers:
    a. Power Flame
    b. Riello
    c. Beckett
3. Boiler shall be constructed in accordance with the provisions of Section IV of the ASME Boiler and Pressure Vessel Code and shall be stamped with the required official ASME symbol. The water boiler maximum working pressure will be 50 PSIG.
4. The entire fuel burner system and its installation shall conform with the manufacturer's erecting instructions, with applicable codes.
5. The gas burner shall be UL listed and certified and shall be of a design which produces flame retention with rapid intimate mixing of the fuel and combustion air. The burner shall be designed to ensure high efficiency and good performance under either balanced draft or forced draft venting conditions. The burner shall be capable of being adjusted to provide 9 1/2% to 10% CO2 for natural gas firing.
6. Controls shall be as required by International Mechanical Code, International Fuel Gas Code, and CSD-1, including operating control, high limit control, two (2) low water controls per each boiler, flame failure control, etc. The boiler and control shall comply with the requirements of FM. Provide two (2) motorized gas shut-off valves for each boiler.
7. One LWCO shall be McDonnell Miller No. 63M.
8. Honeywell Guardring Model RW700A1031.
9. Accessories shall include pressure-temperature-altitude gauge, 50 PSI ASME relief valve.
10. Due to building layout, it may be necessary for boiler to operate at a working pressure of 75 PSI. In the event this is necessary, provide an 80 PSI ASME relief valve and replace the McDonnell Miller No. 63M LWCO with model capable of operating at 80 PSI.
11. Ensure boiler room and installation allows for proper service clearances as recommended by boiler and burner manufacturer. Clearances shall include space for removal of burner, opening of burner door(s), and space for boiler/section removal. Include sufficient space for maintenance of boiler components and internals.

END OF SECTION

SECTION 23 52 24

CONDENSING BOILERS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Boilers with Burner Units

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Comply with the applicable section of the ASME Boiler Code.
   2. Install boilers in accordance with the manufacturer's installation instructions and requirements of International Fuel Gas Code and CSD-1 requirements. Complete work in a neat and workmanlike manner.
   3. ANSI Z21.13/CSA 4.9 (Gas Fired Low Pressure Boilers)
   4. NFPA 54 (ANSI Z221.3) National Fuel Gas Code
   5. Factory Mutual
   6. ASME CSD-1 (Controls and Safety Devices)

C. SUBMITTALS
   1. Shop Drawings and Product Data:
      a. Boilers with Burners
   2. Operating and Maintenance Data:
      a. Boilers with Burners

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Install boilers and surrounding piping and appurtenances so components requiring service are easily accessible and removable.
   2. Provide System Startup, refer Section 23 05 97.
   3. Provide Demonstrations, refer Section 23 05 97.
   4. Review boiler manufacturer's instructions for the installation of multiple boiler systems. Boiler systems utilizing three or more boilers shall include boiler isolation valves.
   5. Review boiler manufactures instructions and recommendations for combustion air and flue requirements. Specify common combustion air where space in existing building does not allow for individual connections. Specify individual boiler flues where possible. Where space is not available common vents may be specified. Refer to boiler manufactures recommendations for flue sizing, All common flue systems shall be engineered systems.
   6. Specify individual gas connections utilizing individual regulators whenever possible. Headered systems utilizing a single gas pressure regulator are not recommended.
   7. For multiple boiler systems, specify manufacturer's boiler control panel to allow for multiple boiler operations. Control panel shall allow for any boiler to be taken offline for service, without losing control from the DDC system. DDC system shall provide control for supply water temperature setpoint, and boiler alarm indications. General boiler alarms are not acceptable. Daisy chained control from a primary boiler is not recommended unless when primary boiler is taken out for service, remaining boilers re-assign primary boiler control.
   8. Condensing boiler shall include stainless steel pressure vessel and tubes. Cast aluminum, cast iron, copper finned, or similar materials are not approved for condensing boiler applications.

E. CERTIFICATIONS
   1. Manufacturer's Certification: The boiler manufacture shall certify the following:
      a. The products and systems furnished are in strict compliance with the specifications.

b. The boiler, burner and associated mechanical and electrical equipment have been properly coordinated and integrated to provide a complete and operable boiler.
c. ASME certification.
d. CSA (AGA/CGA certification.
e. Specified factory tests have been satisfactorily performed.
f. The equipment furnished contains inter-changeable parts with the specified equipment so that all major equipment parts can be obtained from the specified manufacturer.

2. Contractor's Certification: the contractor shall certify the following:
a. The products and systems installed are in compliance with the Contract Documents and all applicable local and state codes.
b. Specified field tests have been satisfactorily performed.
c. The equipment furnished contains inter-changeable parts with the specified equipment so that all major equipment parts can be obtained from the specified manufacturer.

F. DELIVERY, STORAGE AND HANDLING
1. The Contractor shall be responsible for the timely delivery of equipment at the jobsite. The Contractor shall be responsible for unloading and rigging equipment from weather, humidity and temperature conditions, dirt, dust, and other contaminants, as well as jobsite conditions during construction.
2. Equipment shall be unloaded, handled, and stored in accordance with manufacturer's handling and storage instructions.

PART 2 – PRODUCTS

A. BOILERS
1. Acceptable Manufacturers:
a. Aerco (Benchmark)
b. Fulton (Endura, Endura +, Endura XE)
c. Lochinvar (Crest)

2. Boiler shall be constructed in accordance with the provisions of Section IV of the ASME Boiler and Pressure Vessel Code and shall be stamped with the required official ASME symbol. The water boiler maximum working pressure will be 80 PSIG.
3. The entire fuel burner system and its installation shall conform with the manufacture's erecting instructions, with applicable codes.
4. Burner shall incorporate all necessary devices and controls to make a complete fuel burning system for natural gas and bear the listing label of UL evidencing compliance with the requirements of UL-795 and meet CSD-1 and FM codes for gas burners. The burner shall be full modulating whereby the firing rate is infinitely proportional at any firing rate between 20% to 100% as determined by control input signal. The burner shall be designed to insure high efficiency and good performance under either balanced draft or forded draft venting conditions. The burner shall be capable of being adjusted to provide no less than 9 1.2% CO_2, 4.5% O_2, 200 ppm CO at full firing with natural gas. Burner shall be Power Flame or Webster and sized to provide the output at altitude.
5. Controls shall be as required by International Mechanical Code, International Fuel Gas Code, and CSD-1, including operating control, high limit control, and motorized gas shut-off valves for each boiler.
a. LWCO to be factory installed.
b. Provide factory integrated and provided flame guard.
6. Accessories shall include pressure-temperature-altitude gauge, 50 PSI ASME relief valve.

7. Provide acid neutralization interceptor for boiler condensate.
8. Boiler to be certified for installation with Category IV venting (stack) as defined in NFPA 54 (ANSI Z221). Flue material shall be AL294C.

END OF SECTION

SECTION 23 64 00

AIR COOLED LIQUID CHILLER

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Chiller

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Chiller Factory Test: Unit shall be run under full load conditions at factory on laboratory type calorimeter to check overall unit performance including capacity (tons and KW), vibration, operation controls, and safety cutout performance.
   2. Conform to ANSI/ARI 590 Standard for testing and rating of Positive Displacement Compressor Water – Chilling Packages or conform to ANSI/ARI 550 Standard for testing and rating of Centrifugal and Rotary Screw Water – Chilling Packages.
   3. Conform to ANSI/UL 465 Code for construction of water chillers and provide UL label. In the even the unit is not UL approved, the manufacture shall, at his expense, provide for a field inspection by a UL representative to verify conformance to UL standards. If necessary, contractor shall perform modifications to the unit to comply with UL, as directed by the UL representative.
   4. Conform to ANSI/ASME SEC 8 Boiler and Pressure Vessel Code for construction and testing of water chillers.
   5. Conform to ANSI/ASHRAE 15 code for construction and operation of water chillers.
   6. Warranty: Provide five (5) year manufacturer's warranty to include coverage for complete chiller package as manufactured and delivered to site including materials and labor.

C. SUBMITTALS
   1. Shop Drawings:
      a. Chiller
   2. Operating and Maintenance Data:
      a. Chiller

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Specify air cooled chillers with sound attenuation package for compressor section and condenser fans. Sound attenuation shall comply with section 23 00 02 and 23 05 48. Specify sound requirements on construction documents. Sound package shall be reviewed with District prior to issue of construction documents.
   2. Louvered panels over compressor section and all exposed components for rodent and bird protection. Condenser coil hail guards for condenser coils. Angled condenser coils require condenser coil hail guards, louvered panels for condenser section.
   3. Construction and Finish: Units shall be constructed of welded steel frame with a 12-gauge galvanized steel cabinet. Unit shall be finished with a baked-on power paint for panels and control boxes, the structural base shall be finished with air dry paint.
   3. Evaporator: The evaporator shall have independent refrigerant circuits with gasketed evaporator heads. Chiller shall include a minimum of two refrigerant circuits. The evaporator shall be shell-and-tube design with seamless copper tubes roller-expanded into tube sheets or multi-circuit brazed plate type with individually brazed stainless steel plates. Evaporator shall be designed, tested and stamped in accordance with ASME code for a refrigerant side working pressure of 300 PSIG. Waterside working pressure shall be 215 PSIG. Insulation shall be 3/4" flexible closed cell with a maximum K value of 0.26. A water drain connection, bulb wells for the temperature controller, and low temperature cutout, and flare connections.

on water inlet and outlet for pressure drop measurements shall provided. Heater tapes protect evaporator and all internal water piping down to an ambient of - 20°F.

4. Condenser:
    a. Air-cooled condenser coils shall be circuited and upright with configurator aluminum fins mechanically bonded and seamless copper tubing. Condenser shall include integral sub cooling circuit with liquid accumulators. All condensers shall be factory air under water leak-tested at 506 PSIG air pressure.
    b. Condenser fan shall be direct drive, vertical discharge, statically and dynamically balanced. Condenser fan motors shall be 3-phase with permanently lubricated ball bearing and 3-phase thermal overload protection.
    c. Standard low ambient units start and operate to 0°F ambient.
5. Compressor and Lube Oil System:
    a. Screw Type Compressors: Construct semi-hermetic helical rotary screw compressors with head treated forged steel or ductile iron shafts, discharge valves, and sealing surface immersed in oil. Rotors shall be of high-grade steel or cast-iron alloy.
    b. Scroll Type Compressors:
    c. Statically and dynamically balance rotating parts.
    d. Provide oil lubrication system with oil charging valve and oil filter to ensure adequate lubrication during starting, stopping and normal operation.
    e. Provide compressor with automatic capacity reduction equipment consisting of capacity control slide valve. Compressor must start unloaded for soft start on motors.
    f. Provide constant speed (3600 RPM) compressor motor, suction gas cooled with solid state sensor and electronic winding overheating protection, designed for across-the-line or star delta starting. Furnish with start. Compressor motor power factor shall be .90, power factor correction capacitors must be installed.
6. Refrigeration Circuits: Each Unit has two refrigerant circuits. Each refrigerant circuit includes: A compressor suction and discharge service valve, liquid line shutoff valve, removable core filter drier, liquid line sight glass with moisture indicator, charging port and an electronic expansion valve. Fully modulating compressors and electronic expansion valves provide variable capacity modulation over the entire operating range.
    a. Capacity modulation:
        - Screw Chiller: Provide capacity modulation by either slide valve or unloader valves. Unit shall be capable of operation down to 10%. In the event a manufacture cannot provide unit with modulation down to 10%, Hot Gas Bypass must be provided with limitations in accordance with the International Energy Conservation Code.
        - Scroll Chiller: Provide variable speed scroll compressor(s) for capacity control. A minimum of one variable speed scroll compressor shall be specified for each chiller.
7. Control Panel:
    a. Each weather-tight control panel has started and refrigeration controls in separate sections. Starter section has internal access door, main single-point power connection terminal block and customer connection junction box provided with knockouts for remote interlocks. Starter section also contains power controls for part wind start (Star Wye Delta closed transition starter), thermal black for control power function, terminal strip, compressor starter relay, reset relay and non-recycling compressor overload relay.
    b. Provide the following safety controls with indicating lights or diagnostic readouts.
        - Low chilled water temperature protection.
        - High refrigerant pressure.
        - Low oil flow protection.
        - Loss of chilled water flow.
        - Contact for remote emergency shutdown.
        - Loss of refrigerant charge protection.

- Motor current overload

Phase reversal/unbalance/single phasing.
- Over/under voltage.
- Failure of water temperature sensor used by controller.
- Compressor status (on or off).

c. Provide the following operating controls:
- Eight (8) or more step leaving chilled water temperature controller which cycles compressors and activates cylinder unloaders or slide valve based on PI algorithms. If manufacturer is unable to provide at least 8 steps of unloading, providing hot gas bypass shall be required.
- Five-minute solid state anti-recycle timer to prevent compressor from short cycling.

d. Provide ammeters for each compressor or digital display of % RLA on microprocessor.

e. Provide remote mounted alarm and display panel with a minimum of the following features:
- Leaving chiller water temperature set point adjustment.
- Display diagnostics.
- Display entering and leaving water temperatures.
- Display active chilled water and current limit set point.
- Display ambient temperature.
- Display parts failures:
- Water temperature and ambient temperature sensors
- Motor contactors
- Unit Controller
- Condenser and evaporator refrigerant temperature sensors.

8. DDC Sequential Panel
   a. General: A microprocessor-based control panel shall provide chiller plant control for two chillers. The control panel shall be factory programmed and require only minimal configuration at the job site. The chiller sequencing software shall incorporate the following features and control strategies.
   b. Piping System Options: The sequencing panel shall support single pump per chiller, single system pump, or decoupled systems as required in the specification.
   c. System Enable: System start shall be initiated either by a time clock or generic BAS systems though the closure of a set of binary contacts or by the operator from the DDC Sequencing Panel key pad.
   d. Set point Control: The system chilled water set point shall be operator adjustable though the panel keypad and display.
   e. Chilled Water Reset: The sequencing panel software shall provide the option of either load based, or ambient based chilled water reset.
   f. Soft Loading: A soft loading function shall prevent start of the lag chiller during initial chilled water loop pulldown for twice the normal delay.
9. Coordination: Coordinate control functions and connections with Temperature Control Contractor.
10. Completion Services
    a. Start-Up Services: Start up system in accordance with Section 23 05 97. Manufacture shall furnish a factory trained representative without charge for five (5) working days.
    b. Demonstration: Manufacturer’s representative shall instruct the Owner’s personnel in accordance with Section 23 05 95.

PART 2 PRODUCTS

A. CHILLER
   1. Acceptable Manufactures:
      a. Trane
      b. S m a r d t

c. York/Johnson Controls (JCI)

2. Model and Size: As indicated on Drawings.
3. General: Air-Cooled water chiller shall be furnished complete with compressor(s), factory-mounted condenser, evaporator, thermal expansion valve(s) and control panel. Units to have a minimum of two completely independent refrigerant circuits. All units shall ship with a full operating charge of refrigerant and oil.

END OF SECTION

SECTION 23 64 16

WATER COOLED CENTRIFUGAL CHILLER

PART 1 – GENERAL

A. SUNNARY – SECTION INCLUDES
   1. Chiller

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. Chiller Test: Unit shall be run under full load conditions at factory to check overall unit performance, including capacity (tons and KW), operation controls and safety cutout performance. Provide test report at conditions scheduled and under ARI conditions.
      a. Vibration test report by factory submitted to Owner.
   2. ARI 550 – Centrifugal or Rotary Water-Chilling Packages.
   3. ASHRAE 15 – Safety Code for Mechanical Refrigeration.
   4. NEC – National Electrical Code.
   5. ASME SEC 8 – Boiler and Pressure Vessel Code.
   6. NEMA MG1 – Motors and Generators.
   7. ARI 575 – Method of Measuring Machinery sound within an Equipment Space.
   8. ANSI – Safety codes for Mechanical Refrigeration
   9. Warranty: Provide five (5) year manufacturer's warranty to include coverage for complete chiller package as manufactured and delivered to site including materials and labor.

C. SUBMITTALS
   1. Shop Drawings:
      a. Chiller
      b. Manufacturer's Certificate: Certify that components of package not furnished by manufacturer have been selected in accordance with manufacturer's requirements.
      c. Test Report: Indicated energy input versus cooling load output from 35% to 100% of full load at specified and minimum condenser water temperature of 68° F.
   2. Operating and Maintenance Data:
      a. Chiller: Include start-up instructions, maintenance data, parts list controls and accessories. Include trouble-shooting guide.

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Manufactured Units
      a. Provide factory assembled and tested, packaged, water cooled, liquid chillers consisting of centrifugal compressors, compressor motor, condenser, evaporator, refrigeration accessories, pressure relief devices, rupture disks, all instrumentation and controls, auxiliary components and accessories. Construction and ratings shall be in accordance with ARI 550.
      b. Units shall have Energy Efficiency Rating (EER) not less than prescribed by ASHRAE 90A.
      c. Conform to ARI 550 Code for testing and rating of centrifugal chillers.
      d. Conform to UL 465 code for construction of centrifugal chillers and provide UL label.
      e. Conform to ASME SEC 8 for construction and testing of centrifugal chillers.
      f. Conform to ASHRAE 15 code for construction and operation of centrifugal chillers.
      g. Chiller and accessories shall be selected for operation above 6000 feet elevation.
      h. Self-exited vibration velocity shall be less than 0.10 inch/second in any of the three axes.

i. Manufacturer of the chiller shall provide noise criteria (NC) sound level across all octave band center frequencies for scheduled cooling capacities.

2. Compressor
   a. Compressor Casing: Cast iron, horizontally or vertically split with machined passages, leak tested with refrigerant trace gas to 45 PSIG.
   b. Impeller: Single or multi-stage, in-line design, fully shrouded, statically, and dynamically balanced, tested to 20% over operation speed, mounted on heat treated forged or rolled steel shaft, nonferrous, labyrinth seals between stages.
   c. Guide Vanes: Modulating radical blade dampers, on each stage, with externally mounted electric operator, suitable for capacity reduction to 10% of specified load without hot gas bypass when supplied with design entering water quantity and 80° F design temperature entering condenser water.
   d. Bearings: Babbitt lined sleeve bearings, self-aligning, pressure lubricated.
   e. Gear Box: Double helical design, symmetrical and center supported by spherically seated, self-aligning bearing, arranged for inspection without disassembly.
   f. Motor: Hermetically sealed, singled speed, low slop induction type. If an open motor design is used, then the manufacture shall state the heat dissipation to the room and maximum allowable ambient room temperature with submittals.
   g. Lubrication: Direct drive, positive displacement, hermetic motor driven oil pump, with oil cooler, pressure regulator, oil filters, thermostatically controlled oil heater and motor controls, Interlock to start before chiller motor and run after motor is shut down. Provide sight glass for monitoring oil level.
   h. Relief valve in compressor circuit.
3. Evaporator
   a. Provide evaporator of shell and tube type, seamless or welded steel construction with cast iron or fabricated steel heads, seamless copper tubes or red brass tubes with integral finds, rolled or silver brazed into tube sheets. Space tube support sheets approximately 2.5 feet. Minimum tube thickness 0.035 inches.
   b. Design, test and stamp refrigerant side for a tested pressure equal to 1.3 times the maximum operating pressure but not less than 100 PSIG working pressure and water side for 1.5 times the maximum operating pressure but not less than 150 PSIG working pressure, in accordance with ASME SEC 8.
   c. Provide standard type water boxes, machine welded to heat exchanger with tapped drain and vent connections, and flanged or mechanical joint connections arranged to permit inspection of tubes from either end without distributing refrigerant.
   d. Provide combination pressure relief valve – rupture disk on shell in accordance with ASHRAE 15. The resettable pressure relief valve shall be installed downstream of the rupture disk to function as a secondary pressure relieving device which is capable of resetting after safe chiller pressure has been established.
   e. Construction and materials shall conform to ASME SEC. 8.
   f. Inlet piping shall have pressure relief valve, furnished by installing contractor.
4. Condenser
   a. Provide condenser of shell and tube type, seamless or welded steel construction with cast iron or fabricated steel heads, seamless copper tubes or red brass tubes with integral fins, rolled or silver brazed into tube sheets. Space support sheets approximately 2.5 feet. Minimum tube thickness 0.035 inches.
   b. Design, test and stamp refrigerant side for a tested pressure equal to 1.3 times the maximum operating pressure but not less than 100 PSIG working pressure and water side for 1.5 times the maximum operating pressure but not less than 150 PSIG working pressure, in accordance with ASME SEC 8.

c. Provide standard type water boxes, machine welded to heat exchanger with tapped rain and vent connections, and flanged or mechanical joint connections arranged to permit inspections of tubes from either end without disturbing refrigerant.
d. Provide combination pressure relief valve – rupture disk on shell in accordance with ASHRAE 15. The resettable pressure relief valve shall be installed downstream of the carbon rupture disk to function as a secondary pressure relieving device which is capable of resetting after safe chiller pressure has been established.
e. Construction and material shall conform to ASME SEC 8.
f. Inlet piping shall have pressure relief valve, furnished by installing contractor.

5. Purge System: Provide purge system that can operate independently of the chiller and operate which the machine circulation water pump is shut down. Purge system to operate automatically for removing any non-condensable discharge and refrigerant return. Remove water with manual blow-off valve.
6. Refrigerant Monitor: Provide a refrigerant monitor that can be calibrated for appropriate refrigerant, capable of detecting concentrations of 10 PPM for low level leak detection when proposing Class B1 refrigerant.
7. Controls
   a. On or near chiller, mount steel control panel containing solid state fully automatic operating and safety controls.
   b. Provide the following safety controls arranged so that operating any one will shut down machine and require manual reset:
      1. Low evaporator refrigerant temperate.
      2. High condenser refrigerant pressure.
      3. Low Oil pressure
      4. High oil temperature.
      5. High motor current.
      6. Low refrigerant (evaporator) pressure.
      7. Dry contact for remote trouble indication.
      8. No starter transition.
      9. Low chilled water temperature.
      10. Low flow reading from the chilled water flow switch.
      11. Remote shut down from Building Automation System.
      12. Loss of condenser water flow.
   c. Provide the following devices on control panel:
      1. Manual Switches:
         i. Machine off-auto switch.
         ii. Oil pump switch (automatic).
      2. Manual set Point Adjustments:
         i. Leaving chilled water temperature (between 45° F and 55° F).
         ii. Current Demand Limit
      3. Status Lights/ Pressure Gauges:
         i. Unit running, including remote status via contact closure.
         ii. Unit loading, including remote load status output @ 4-20 mA DC.
         iii. Unit unloading.
         iv. Evaporator refrigerant pressure.
         v. Condenser refrigerant pressure.
         vi. Low oil pressure (oil sump).
         vii. High pressure (oil supply).
         viii. Chiller trouble alarm, via contact closure.
         ix. Start-up in progress.
         x. Anti-recycle timer active.
         xi. Condenser water pump on.

xii. Chilled water pump on.
xiii. Oil Pump on.
xiv. Chiller on.

4. Set point and Temperature Display:
   i. Chilled water set point.
   ii. Current limit set point.
   iii. Entering evaporator water temperature.
   iv. Leaving evaporator water temperature.
   v. Entering condenser water temperature.
   vi. Leaving condenser water temperature.

d. Provide the following operating controls:
   1. Solid state, chilled water temperature controller which controls hydraulically operated guide vane operator. Locate temperature sensor in entering and leaving chilled water.
   2. Adjustable thirty minute off time prevents compressor from short cycling.
   3. Demand limit device to manually set maximum current infinitely between 35% and 100% of full load amperes.
   4. Automation System shall enable chiller.

8. Starter
   a. Acceptable Manufactures
      1. Cutler Hammer
      2. Square D
      3. GE
   b. On chiller, mount steel NEMA 1 type enclosure, containing Star-Delta closed transition start, manufactured in accordance with chiller manufacturer's specifications and factory tested.
   c. Enclosure shall be designed for top or bottom cable entry with from access. Dorr, interlocked with circuit breaker, shall accommodate padlock.
   d. Mount the following devices within enclosure:
      1. Disconnect switch on line side with fuses.
      2. High interrupting capacity circuit breaker with ground fault protection.
      3. Pilot relays to start and stop compressor on signal from chiller control panel.
      4. Solid state microprocessor-based motor overload protection protects compressor motor from distribution system irregularities and provides motor current signal to chiller capacity control module.
      5. Control power transformer.
      6. Fused control circuits for control circuit, oil pump motor, oil heater and purge control unit.
      7. Capacitors, one per phase to correct power factor to minimum 90%.
      8. Relay for remote mounted emergency shut-down switch.
   e. Provide the following devices or alternatively solid-state microprocessor-based motor overload protection display panel on starter door.
      1. Starter fault trip indicator and reset.
      2. Overload trip indicator and reset.
      3. Ground fault trip indicator and reset.
      4. Ammeters, one per phase.
      5. Voltmeters, one per phase.
   f. Distribution fault protection to prevent re-connection of the compressor motor while it is out-of-phase with the line voltage. If a distribution fault is detected, the fault trip indicator shall be displayed, and a manual reset shall be required. Distribution faults of 1 ½" electrical cycle durations shall be detected on the compressor motor shall be disconnected within six electrical circles.

9. Coordination: Coordinate control functions and connections with Temperature Control Contractor.
10. Completion Services
    a. Start-Up Services: Start up system in accordance with Section 23 05 97.
        1. Provide services of factory trained representative for minimum 2 days to leak test, refrigerant pressure test, evacuate, dehydrate, charge, start-up, calibrate controls, instruct Owner on operation and maintenance.
        2. Supply initial charge of refrigerant and oil.
    b. Demonstration: Manufacturer's representative shall instruct the Owner's personnel accordance with Section 23 05 9. Verify specified performance.

PART 2 – PRODUCTS

A. CHILLERS
    1. Acceptable Manufacturers:
        a. Trane
        b. Smardt
        c. York/Johnson Controls (JCI)

END OF SECTION

SECTION 23 64 36

AIR COOLED CONDENSING UNITS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Air cooled refrigerant condensing units

B. REFERENCES STANDARDS (MINIMUM CRITERIA)
   1. ASHRAE Std 15 - Safety Standard for Refrigeration Systems; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; (ANSI/ASHRAE Std 15).
   2. ASHRAE Std 20 - Methods of Testing for Rating Remote Mechanical-Draft Air-Cooled Refrigerant Condensers; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc...
   3. ASHRAE Std 90.1 - Energy Standard for Buildings Except Low-Rise Residential Buildings; American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.; Latest Edition, Including All Addenda (ANSI/ASHRAE/IES Std 90.1)
   4. UL 207 - Refrigerant-Containing Components and Accessories, Nonelectrical; Underwriters Laboratories Inc.; Current Edition, Including All Revisions
   5. Provide five (5) years warranty on compressors as manufactured and delivered to site including materials and labor.

C. SUBMITTALS
   1. Shop Drawings.
   2. Manufacturer’s Certificate: Certify that components of package not furnished by manufacturer have been selected in accordance with manufacturer’s requirements.
   3. Operating and maintenance Data:
      a. Air cooled condenser: Include start-up instructions, maintenance data, parts list, controls and accessories. Include trouble-shooting guide.

D. RESTRICTIONS/CRITICAL CRITERIA
   1. For units to be installed in sound sensitive areas specify with sound attenuation package for compressor section and condenser fans. Sound attenuation shall comply with section 23 00 02 and 23 05 48. Specify sound requirements on construction documents. Sound package shall be reviewed with District prior to issue of construction documents.
   2. General: Factory assembled, piped, internally wired, and fully charged. Designed to operate at outdoor ambient temperatures as high as 115 degrees F. Designed for outdoor rooftop or ground level installation.
      a. Units 7-1/2 tons and greater shall have a minimum of dual compressors with separate refrigeration circuits.
      b. Provide multiple compressor units with means of capacity modulation by variable speed compressor, inverter compressor, or similar capacity controls. Hot gas bypass may be utilized on limited applications although is not preferred. Hot gas bypass shall be limited in capacity as required in the International Energy Conservation Code.
   3. Cooling: Rated in accordance with ARI Standards
   4. Refrigerant Controls: Refrigerant controls include condenser fan, and compressor contactors, and 24V transformer. Safety controls include high- and low-pressure controls and compressor overloads.
   5. Compressors: Compressors shall be 3600 RPM hermetic sealed compressors and shall be equipped with over temperature, over current and high-pressure controls. Provide crankcase heaters. Compressors shall have five (5) year warranty.

6. Condenser Coil: Condenser coil shall be seamless copper tubing mechanically bonded to aluminum fins. Factory pressure and leak tested at 450 PSIG. Units are dual circuited.
7. Condenser Coils: aluminum fins mechanically bonded to seamless copper tubing.
   a. Condenser coil hail guard and rodent protection. Provide unit with louvered guard consisting of 1/2”x1/2” wire fabric secured to unit exterior with galvanized or aluminum strips. Guards shall be removable to allow for service and access to coil sections.
8. Condenser Fan: Condenser fan shall be direct drive, statically and dynamically balanced, up flow propeller type. Weatherproofed permanently split capacitor fan motor shall have built-in thermal overload, permanently lubricated sleeve bearings and be U.L. listed for outdoor use.
9. Controls: Refer to sections 23 09 00 and 23 09 90 for control components and sequences of operations.
10. Start-up Services: Start up system in accordance with Section 23 05 97. Manufacturer shall furnish a factory trained representative without charge for five (5) working days.
11. Demonstration: Manufacturer’s representative shall instruct the Owner’s personnel in accordance with Section 23 05 95.

PART 2 – PRODUCTS

A. ACCEPTABLE MANUFACTURES.
   1. Trane
   2. Carrier
   3. York/Johnson Controls (JCI)
   4. Approved Substitute

END OF SECTION

SECTION 23 65 12

INDUCED DRAFT COOLING TOWER

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Cooling Tower

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. ANSI/AFBMA 9 – Load Rating and Fatigue Life for Ball Bearings.
   2. ANSI/AFBMA 11 – Load Rating and Fatigue Life for Roller Bearings.
   3. ASME PTC-23 – Atmospheric Water-Cooling Equipment.
   4. CTI ATC-105 – Acceptance Test Code for Water Cooling Towers.
   5. CTI – Certification Standard STD-201.
   6. NEMA 250 – Enclosure for Electrical Equipment (1000 Volts maximum).
   7. NEC – National Electrical Code.
   8. Warranty: Provide five (5) year warranty.
   9. Extra Materials: Provide one set of matched fan belts, three spray nozzles for each cell, one gasket for each access door, one valve seat for each make-up or control valve.

C. SUBMITTALS
   1. Shop Drawings:
      a. Cooling Tower Product Data : Indicate rated capacities, flow characteristics, nozzle performance, dimensions, weights and point loadings, accessories, required clearances, electrical requirements and wiring diagrams, location, and size of field connections. Submit schematic indicating capacity controls.
      b. Manufacturer’s Certificate: Certify performance, based on CTI STD-201, and submit performance curve plotting leaving water temperature against wet bulb temperature.
      c. Manufacturer’s Installation Instructions: Provide pertinent information for proper installation.
   2. Operating and Maintenance Data:
      a. Cooling Tower: Include star-up instructions, maintenance data, spare and replacement, parts list, controls, and accessories.

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Manufactured Unit
      a. Provide unit for outdoor use, factory assembled, sectional, crossflow, vertical discharge, induced draft type, with sump, fan, surface sections, drift eliminators and motors.
   2. Components
      a. Framework and Casing: Support structure and basin constructed of hot-dip galvanized steel with a minimum coating of 2 ½ ounces per square foot conforming to ASTM A-123 and fiberglass reinforced polyester (FRP).
      b. Louvers: Fiberglass reinforced polyester (FRP) spaced to minimize air resistance and splash out.
      c. Fan: Multi blade, aluminum alloy blades, axial type with one-piece, multi-grooved neoprene/polyester belt drive, bearings with life expectancy of 40,000 hours, with extended grease fittings. Grease packed bearings shall have moisture proof seals and integral slinger rings. Shafts shall be stainless steel.
      d. Motor: Fan motors shall be totally enclosed air over (TEAO) type, high efficiency, reversible, squirrel cage, ball bearing type designed especially for cooling tower service. Motor shall be furnished with special moisture protection on windings, shafts, and bearings. Motor shall be located outside of air stream.

e. Extended lubrication lines shall be provided for easy maintenance utilizing a single point of application.
f. Gear Drive: designed for minimum 150% motor nameplate power.
g. Fan Guard: One-piece, welded steel rod and wire guard, hot dipped galvanized after fabrication over each fan cylinder.
h. Access: Large access doors for access to eliminators and fan plenum. Access doors shall be coordinated with access platform to assure proper alignment of doors and platform.
i. Distribution Basin: Open, gravity type distribution basin utilizing water diffusers and plastic metering orifices.
    1. Individual upper distribution piping fed from main headers equipped with flow control valves so that any cell may be shut down from maintenance without interfering with operation of any other cell.
    2. Low pressure, splash-type distribution nozzles.
    3. Single ASA 125 lb. serrated flat face flanged connection for the hot water inlet.
j. Wet Deck Surface and Drift Eliminators: Formed from polyvinyl chloride (PVC), and shall be impervious to rot, decay and fungus or biological attacks. Drift eliminator shall be 2 pass.
    1. Drift losses shall not exceed 0.2% of cooling tower capacity.
k. Collection Basin: One piece welded self-cleaning stainless steel with depressed center section, including interconnection of cell basins of size to match sump outlet with isolation valves, designed to support tower, with cleanout and drain fitting, ¼" stainless steel mesh strainer, bottom outlet sump with anti-vortex device and removable screen and overflow.
l. Float Valves: Brass or bronze make-up valve with plastic or copper float.
m. Hardware: Nuts, bolts, washers, and nails shall be stainless steel.
n. Finish: Steel components shall be G235 hot dipped galvanized steel with edges protected with zinc rich compound.

3. Accessories
    a. Vibration Cut-Out Switch: Provide vibration cut-out switch mounted on fan support framework to shut off fan when subjected to excessive vibration.
    b. Condenser Water Control System: Electric water control system shall interface with DDC system. The cooling tower manufacturer shall provide the following accessories:
        1. Electric water level control
        2. Low level cutout
        3. Low level alarm
        4. High level alarm
        5. Make-up on
        6. Make-up off
    c. Variable frequency drive or 2-speed fan motor.
    d. Extended lubrication lines.
    e. Sump debris screens.
    f. Mount unit on spring type vibration isolators.
4. Completion Services
    a. Start-Up Services: Start up system in accordance with Section 23 05 97. Manufacture shall furnish a factory trained representative without charge for one (1) working day.
    b. Demonstration: Manufacturer's representative shall instruct the Owner's personnel in accordance with Section 23 05 95.
5. Specify cooling towers with sound mitigation measures. Specify with variable speed and/or quiet fans. Specify specific sound levels for tower on construction documents. Sound levels shall be reviewed prior to issuing of construction documents. Refer to sections 23 00 02 and 23 05 48 for sound requirements.

6. Wherever possible specify towers with bottom outlet connections. Side outlet towers should be avoided whenever possible. Coordinate tower elevations and piping requirements with architectural for enclosures.

PART 2 – PRODUCTS

A. COOLING TOWER
   1. Acceptable Manufacturers:
      a. Baltimore Air Coil Co.
      b. Marley
      c. Evapco

END OF SECTION

SECTION 23 73 13

AIR HANDLING UNITS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Air Handling Units

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. ARI
   2. ANSI

C. SUBMITTALS
   1. Product Data:
      a. Air Handling Units
   2. Operating and Maintenance Data:
      a. Air Handling Units

D. RESTRICTIONS/CRITICAL CRITERIA
   1. Manufacturer of air handling units shall provide noise criteria (NC) sound level across all octave band center frequencies for catalog operating range of unit a gross cooling capacity range. Data shall be obtained in conformance with ANSI S1.32 (American National Standard Methods for the Determination of Sound Power Levels at Discrete Frequency and Narrow Band Noise Sources in Reverberation Rooms) and per AMCA Standard 300-85 test code “Sound Rating Air Moving Devices”/ Provide sound power levels for discharge and return for the supply fan.
   2. Unit Casing: Unit shall be constructed of a complete frame with removable panels. The casing must be able to withstand up to six-inches positive or four-inches negative static pressure. Condensate pan shall be sloped in two planes to ensure complete condensate drainage. Condensate pan shall be double wall construction.
      a. Full sized hinged removable double-wall access doors with two-step safety handles shall be provided for quick access to the interior of the unit casing. Doors attached by screws or doors not continuously gasketed are not acceptable.
      b. Casing Options: Unit shall be double wall constructed to prevent insulation erosion into the airstream and to allow cleaning of the unit interior. Interior wall shall be a minimum of two-inches thick of either 20-guage solid or 18-guage perforated or solid plate galvanized steel. Foil faced insulation is not acceptable.
   3. Insulation: Unit shall be factory insulated with a minimum R-5 insulation system. Insulation shall be fiberglass or foam injected panels. All connecting channels shall be insulated to prevent sweating.
   4. Filter Modules: Filter sections shall have filter racks, an access door for filter removal and block-offs as required to prevent air bypass around filters. Modules shall be supplied with 2-inch angled filters.
   5. Fans
      a. Fans shall be double width, double inlet, multi-blade type as manufactured by the unit manufacturer. Fans shall be forward curve (FC), backward inclined (BI) or backward inclined airfoil (AF) as required for stable operation, refer schedule for fan type. Propeller type exhaust fans are not approved.
      b. Housed fan performance shall be certified as complying with ARI Standard 430-89. Centrifugal fans shall be dynamically balanced at the factory as a complete fan assembly (fan wheel, motor, drive, and belts). Fan shafts shall not exceed 75% of their first critical speed at any cataloged rpm.

c. Fans shall be equipped with self-aligning, anti-friction pillow block bearings with a minimum life of L-50 200,000 hours. Bearings shall be equipped with grease lines allowing for lubrication from one side of the fan.
d. Fan and motor assembly shall be internally isolated from unit casing with spring isolators, furnished and installed by unit manufacturer. Vibration isolators shall be nominal 2-inch static deflection. Fan scroll shall be attached to the unit casing by a flexible canvas duct.
e. Fan Options
    1. Unit sizes 35 and larger shall be provided with a totally enclosed galvanized expanded metal belt guard. The belt guard shall be rigidly attached to the bearing support structure and have a two-piece removable front panel. A tach hole shall be provided opposite the fan shaft. The belt guard shall be a universal size to accommodate any applicable drive.
    2. Grease lines for both bearings shall be extended to the fan support bracket on the drive side.
f. Fan Modulation: For variable volume application air flow shall be modulated by VFD or ECM

6. Motors.
    a. Motors shall be mounted integral to an isolated fan assembly furnished by the unit manufacturer. Motors shall be mounted inside the unit casing. Motors shall be mounted on a slide base to permit adjustment of drive belt tension.
    b. Motors shall be high efficiency with a power factor of 0.85 or higher. Refer Section 23 00 04 for additional requirements.
    c. Motor frame shall be ‘T’ frame.
7. Drives
    a. Drives shall be variable pitch, suitable for adjustment within 5% of specified rpm.
    b. Drives shall be selected at 1.2 service factor.
8. Coils
    a. Coils shall be manufactured by the same company as the supplier of the air handling unit. Coils shall be designed with aluminum plate fins and copper tubes.
    b. Fins shall have collars drawn, belled, and firmly bonded to the tubes by means of mechanical expansion of the tubes. No soldering or tinning shall be used in the bonding process. Coils shall be mounted in the unit casing to be accessible for service and can be removed from the unit either through the side or top. Capacities, pressure drops, and selection procedure shall be certified in accordance with ARI Standard 410.
    c. Water Coils
        1. All coils shall be enclosed in a coil section. Coil headers and U-bends shall not be exposed.
        2. Coils shall have a supply header to ensure distribution of hot water to each tube of coil.
        3. Coils shall be proof tested to 300 psig and leak tested to 200 psig, air pressure underwater.
        4. Maximum 12 fins per inch.
        5. Cooling coils to have fins with ZRC to prevent water carryover. Coils to be capable of operating at 640 FPM with a fin spacing of 10 fins per inch with no water carry over.
        6. Specify sufficient space between coils to allow for installation of controls components, and coil cleaning.
        7. Heating water coil additional criteria: Sufficient space shall be provided within unit to allow for coil, circulation pump piping and service requirements. Coil control valve and circulation pump may not be located above ceilings. For units which do not allow for sufficient space, provide coil piping vestibule. Vestibule shall be of similar construction to units, fully insulated, and include full size access doors. Provide secondary drain pan for heating water coil circulation pump. Extend drain to unit exterior.

d. DX Coils
    1. DX cooling coil, coil shall be seamless copper tubing mechanically bonded to aluminum fins. Factory pressure and leak tested at 450 PSIG.
    2. Coils above 10-tons shall be dual circuited (minimum)
    3. Refrigerant piping shall be in accordance with manufacturer's recommendations for design refrigerant piping lengths and configurations. Refer to section 23 23 00 for refrigerant piping requirements.
    4. Outdoor condensing unit shall be sized to accommodate DX coil requirements. Refer to section 23 64 26 for condensing unit requirements.
    5. Specify sufficient space between coils to allow for installation of controls components, and coil cleaning.

9. Damper Mixing Box, Mixing Box, Filter Mixing Box and Economizer Module: A module shall be provided that supports damper assembly for outside, return and/or exhaust air. Economizer module shall be capable of supporting 100% outside air economizer function. Specify gravity relief air dampers or motorized relief air dampers to enable building pressure control if return air fan is not included in unit construction. Coordinate requirements with building elements such as relief air hoods and relief air fans.
10. Dampers: Dampers shall modulate the volume of outside, return or exhaust air. Dampers shall be double-skin airfoil design with metal compressible jamb seals and extrude vinyl blade edge seals on all blades. The dampers shall be rated for a maximum leakage rate of less than 1 percent of nominal airflow at 1-inch wg. Blades shall rotate on stainless steel sleeve bearings. Dampers shall be arranged in parallel or opposed blade configuration.
11. Installation: When unit is located in crawl space, allow minimum of 12" clearance between unit and bottom of structure.
12. Completion Services
    a. Start-Up Services: start-up system in accordance with Section 23 05 97.
    b. Demonstration: Instruct the Owner's personnel in accordance with Section 23 05 95.
13. Controls:
    a. Controls shall be as specified in accordance with Section 20 09 00. All unit controls shall be TC contractor. Unit control components shall be provided by TC contractor and factory installed.

PART 2 – PRODUCTS

A. AIR HANDLING UNITS
    1. Acceptable Manufacturers (Modular and Package):
        a. AAON
        b. Carrier
        c. Engineered Air
        d. Trane
    2. Acceptable Manufacturers (Custom):
        a. Engineered Air
        b. Mammoth/Temptrol/Governair
        c. Annex Air

END OF SECTION

SECTION 23 74 13

PACKAGE ROOFTOP UNITS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Rooftop HVAC Units

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. ARI

C. SUBMITTALS
   1. Product Data:
      a. Rooftop HVAC Units
   2. Operation and Maintenance Data:
      a. Rooftop HVAC Units

D. RESTRICTIONS/CRITICAL CRITERIA
   1. For units to be installed in sound sensitive areas specify with sound attenuation package for compressor section and condenser fans. Sound attenuation shall comply with section 23 00 02 and 23 05 48. Specify sound requirements on construction documents. Sound package shall be reviewed with District prior to issue of construction documents.
   2. General
      a. Units:
         1. Factory assembled, piped, internally wired, and fully charged with R-410A.
         2. Designed to operate at outdoor ambient temperatures as high as 115 degrees F.
         3. Designed for outdoor rooftop or ground level installation.
         4. Units 7-1/2 tons and greater shall have a minimum of dual compressors with separate refrigeration circuits.
      b. Cooling: Rated in accordance with ARI Standards.
      c. Cooling Units: UL listed and labeled, classified in accordance to UL 1995.
      d. Exterior surfaces: Manufacturers standard finish of baked enamel or painted finish with primer undercoat.
      e. Panels: 20-gauge steel, gasketed and insulated.
   3. Refrigerant Controls: Refrigerant controls include condenser fan, evaporator fan and compressor contactors, and 24V transformer. Safety controls include high- and low-pressure controls and compressor overloads.
   4. Compressors: Compressors shall be 3600 RPM hermetic sealed compressors and shall be equipped with over temperature, over current and high-pressure controls. Provide crankcase heaters. Unit shall be capable of operating at published CFMs on cooling cycle. Compressors shall have five (5) year warranty.
   5. Evaporator Coil: Evaporator coil shall be seamless copper tubing mechanically bonded to aluminum fins. Factory pressure and leak tested at 200 PSIG. Units have two (2) independent circuits.
   6. Drain Pans: Stainless steel evaporator pans internally sealed and insulated. Provide threaded drain connection in evaporator section.
   7. Condenser Coil: Condenser coil shall be seamless copper tubing mechanically bonded to aluminum fins. Factory pressure and leak tested at 450 PSIG. Units are dual circuited.
   8. Indoor Air Fan: Indoor air fan shall belt driven, forward curved, centrifugal type, equipped with adjustable motor sheaves. Provide motor with thermal overload protection. Permanently lubricated fan and motor bearings. Fan drive components are mounted on rubber-in-shear isolators. Motor to be of the high efficiency type.

9. Condenser Fan: Condenser fan shall be direct drive, statically and dynamically balanced, up flow propeller type. Weatherproofed permanently split capacitor fan motor shall have built-in thermal overload, permanently lubricated sleeve bearings and be U.L. listed for outdoor use.
10. Heating Section:
    a. Water Heating Coils:
        1. Coils shall be manufactured by the same company as the supplier of the air handling unit.
        2. Coils shall be mounted in the unit casing to be accessible for service and can be removed from the unit either through the side or top. Capacities, pressure drops, and selection procedure shall be certified in accordance with ARI Standard 410
        3. All coils shall be enclosed in a coil section. Coil headers and U-bends shall not be exposed. Coils shall have a supply header to ensure distribution of hot water to each tube of coil.
        4. Sufficient space shall be provided within unit to allow for coil, circulation pump piping and service requirements. Coil control valve and circulation pump may not be located above ceilings. For units which do not allow for sufficient space, provide coil piping vestibule. Vestibule shall be of similar construction to units, fully insulated, and include full size access doors.
        5. Provide secondary drain pan for heating water coil circulation pump. Extend drain to unit exterior.
    b. Natural Gas Heating Section:
        1. Gas units AGA-approved specifically for outdoor installation.
        2. Heat exchanger: stainless steel or aluminized steel, forced draft blow assembly.
11. Filters: Two (2”) inch throw-away filters.
12. Fans:
    a. Fan and motor assembly shall be internally isolated from unit casing with neoprene or spring isolators, furnished and installed by unit manufacturer.
    b. Motors shall be high efficiency with a power factor of 0.85 or higher. Refer Section 23 00 04 for additional requirements.
    c. Fans shall be forward curve (FC), backward inclined (BI) or backward inclined airfoil (AF) as required for stable operation. Propeller type exhaust fans for unit exhaust/relief are not approved.
13. Accessories and Options: The following factory installed options or field installed accessories shall be provided:
    a. Roof Curb. Roof mounting curb shall be of sufficient height to maintain a minimum of 12” between bottom of rooftop unit and finished roof.
    b. Economizer: The assembly includes Fully modulating 0-100% motor and dampers, minimum position setting, preset linkage, wiring harness with plug and fixed dry bulb control (0-10 VDC or 4-20 MA).
    c. Low ambient compressor lockout control for ambient temperatures at 45°F or less.
    d. Anti-short cycle: A lockout timer provides a minimum off time of five (5) minutes between compressor cycling.
    e. Condenser coil hail guard and rodent protection. Provide unit with louvered guard consisting of 1/2”x1/2” wire fabric secured to unit exterior with galvanized or aluminum strips. Guards shall be removable to allow for service and access to coil sections.
    f. Specify a 115-volt convenience outlet on unit sized to manage a small power load or service light. Outlet shall be powered independently from unit power.
14. Installation
    a. Separate openings for supply and return duct shall be cut in roof. Annular space between roof opening and sheet metal ductwork shall be sealed. Provide Minimum of 4” acoustic insulation within roof curb. Insulation shall consist of rigid fiberglass insulation, rigid foam

insulation, or fiberglass batt insulation. Joints shall be staggered and taped. In lieu of fiberglass insulation 4” thick light weight concrete may be used.

15. Controls:
    a. Refer to sections 23 09 00 and 23 09 90 for control components and sequences of operations.
16. Completion of Services
    a. Demonstration: Manufacturer’s representative shall instruct the Owner’s personnel in accordance with Section 23 05 95.
    b. Start-up: Refer Section 23 05 97.

PART 2 – PRODUCTS

A. ACCEPTABLE MANUFACTURERS
    1. Rooftop HVAC Units:
        a. Trane
        b. Aaon
        c. York; Johnson Controls (JCI)
        d. Engineered Air

END OF SECTION

SECTION 23 74 33

MAKE-UP AIR UNITS

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Rooftop Make-up Air Units

B. REFERENCED STANDARDS (MINIMUM CRITERIA)
   1. ARI

C. SUBMITTALS
   1. Product Data:
      a. Make-up Air Units
   2. Operation and Maintenance Data:
      a. Make-up Air Units

D. RESTRICTIONS/CRITICAL CRITERIA
   1. For units to be installed in sound sensitive areas specify with sound attenuation package for compressor section and condenser fans. Sound attenuation shall comply with section 23 00 02 and 23 05 48. Specify sound requirements on construction documents. Sound package shall be reviewed with District prior to issue of construction documents.
   2. General
      a. Units:
         1. Factory assembled and internally wired.
         2. Designed to operate at outdoor ambient temperatures as high as 115 degrees F. for cooling, and as low as -10 degrees F for heating.
         3. Designed for outdoor rooftop or ground level installation utilizing natural gas heating section or heating water coil section.
         4. Provide evaporative cooling section where required by District for units serving as space cooling. DX cooling may be utilized at request from District.
      b. Exterior surfaces: Manufacturers standard finish of baked enamel or painted finish with primer undercoat.
      c. Panels: 20-gauge steel, gasketed and insulated.
   3. Drain Pans: Stainless steel evaporator pans internally sealed and insulated. Provide threaded drain connection in evaporator section.
   4. Indoor Air Fan: Indoor air fan shall belt driven, forward curved, centrifugal type, equipped with adjustable motor sheaves. Provide motor with thermal overload protection. Permanently lubricated fan and motor bearings. Fan drive components are mounted on rubber-in-shear isolators. Motor to be of the high efficiency type.
   5. Heating Section:
      a. Water Heating Coils:
         1. Coils shall be manufactured by the same company as the supplier of the air handling unit.
         2. Coils shall be mounted in the unit casing to be accessible for service and can be removed from the unit either through the side or top. Capacities, pressure drops, and selection procedure shall be certified in accordance with ARI Standard 410
         3. All coils shall be enclosed in a coil section. Coil headers and U-bends shall not be exposed. Coils shall have a supply header to ensure distribution of hot water to each tube of coil.
         4. Sufficient space shall be provided within unit to allow for coil, circulation pump piping and service requirements. Coil control valve and circulation pump may not be located

above ceilings. For units which do not allow for sufficient space, provide coil piping vestibule. Vestibule shall be of similar construction to units, fully insulated, and include full size access doors.
5. Provide secondary drain pan for heating water coil circulation pump. Extend drain to unit exterior.

b. Natural Gas Heating Section:
1. Gas units AGA-approved specifically for outdoor installation.
2. Heat exchanger: stainless steel, forced draft blow assembly suitable for specific application.

6. Evaporative Cooling Section:
a. Factory assembled including evaporative cooling media, reservoir, internal circulation pump, and automatic drain/fill kit.
b. Drain/fill kit shall include outdoor air temperature sensor to automatically drain unit when outside air temperatures are below 45 degrees F, and automatically fill when outside air temperatures are above 65 degrees F.

7. Filters: Two (2”) inch throw-away filters.
8. Accessories and Options: The following factory installed options or field installed accessories shall be provided:
a. Roof Curb. Roof mounting curb shall be of sufficient height to maintain a minimum of 12” between bottom of rooftop unit and finished roof.
b. Specify a 115-volt convenience outlet on unit sized to handle a small power load or service light. Outlet shall be powered independently from unit power.

9. Installation
a. Separate openings for supply and return duct (where applicable) shall be cut in roof. Annular space between roof opening and sheet metal ductwork shall be sealed. Provide Minimum of 4” acoustic insulation within roof curb. Insulation shall consist of rigid fiberglass insulation, rigid foam insulation, or fiberglass batt insulation. Joints shall be staggered and taped. In lieu of fiberglass insulation 4” thick light weight concrete may be used.

10. Controls:
a. Refer to sections 23 09 00 and 23 09 90 for control components and sequences of operations.

11. Completion of Services
a. Demonstration: Manufacturer’s representative shall instruct the Owner’s personnel in accordance with Section 23 05 95.
b. Start-up: Refer Section 23 05 97.

PART 2 – PRODUCTS

A. ACCEPTABLE MANUFACTURERS
1. Make-up Air Units:
a. Greenheck
b. Reznor
c. Sterling
d. Trane

END OF SECTION

SECTION 23 82 15

HEAT TRANSFER – HYDRONIC

PART 1 – GENERAL

A. SUMMARY – SECTION INCLUDES
   1. Convectors/Fin Tube
   2. Cabinet Heaters
   3. Unit Heaters
   4. Fan Coils
   5. Duct Coils

B. REFERENCE STANDARDS (MINIMUM CRITERIA)
   1. ARI Standard 410

C. RESTRICTIONS/CRITICAL CRITERIA
   1. Unit heaters shall utilize unitary controls. Specify unit mounted or wall mounted thermostat. Unit heater coil runs-wild and fan cycles to maintain temperatures.
   2. Coordinate with District and temperature control requirements for control of cabinet unit heaters and convectors.
      a. Cabinet unit heaters serving vestibules and entry ways shall utilize wall mounted stand-alone controls. Specify pipe mounted Aquastat to enable fan when water temperature exceeds 120 deg F. Specify wall mounted thermostat to cycle fan.
      b. Cabinet unit heaters serving occupied spaces such as classrooms, toilet rooms, and storage rooms shall utilize temperature control systems. Specify TCV and DDC thermostat.
      c. Specify DDC thermostats and TCV for convectors and fin tube to maintain space temperature in occupied spaces. In un-occupied spaces coordinate with district for means of control. Self-contained thermostatic valves may be acceptable if located below unit covers.
   3. Locate fan coil unit above accessible ceiling only. The use of fan coil unit directly above occupied spaces such as offices and classrooms is discouraged. Review fan coil unit locations with District prior to submittal of construction documents for approval.

D. SUBMITTALS
   4. Product Data:
      d. Convectors
      e. Cabinet Heaters
      f. Unit Heaters
      g. Fan Coils
      h. Duct Coils
   5. Operating and Maintenance Data:
      a. Convectors
      b. Cabinet Heaters
      c. Unit Heaters
      d. Fan Coils
      e. Duct Coils

PART 2 – PRODUCTS

A. DUCT COIL
   1. Acceptable Manufacturers:

a. Trane
b. Sigma
c. Precision Coils

2. Fins: Configured, aluminum plate fins are positioned continuously across entire coil width. Fins are die-formed in multiple stages with full fin collars for maximum fin-tube contact and accurate spacing. Fins are mechanically bonded to the tubes for lasting reliability.
3. ARI: Coils must be certified in accordance with ARI Standard 410.

B. CONVECTORS/FIN TUBE
1. Acceptable Manufacturers:
a. Trane
b. Sterling
c. Vulcan
2. Minimum 16-gauge steel casing with baked enamel finish, color as selected by Architect.

C. CABINET HEATERS
1. Acceptable Manufacturers:
a. Trane
b. Sterling
c. Vulcan
d. Modine
2. Cabinet: Minimum 16-gauge steel, insulated from panel, hinged bottom panel on recessed models, tamperproof access panels and doors, stamped grills, color as selected by Architect.
3. ARI: Coils must be certified in accordance with ARI Standard 410.
4. Filters: 1” throw-away. Not required on horizontal units.

D. UNIT HEATERS
1. Acceptable Manufacturers:
a. Trane
b. Sterling
c. Vulcan
d. Modine
2. Coil: Aluminum fin on copper tube, serpentine.

E. FAN COIL
1. Acceptable Manufacturers:
a. Trane
b. Enviro-Tec
2. ARI: Coils must be certified in accordance with ARI Standard 410
3. Filters: 1” throw-away.
4. Cabinet: Minimum 16-gauge steel, insulated from panel, hinged bottom or side access panels, tamperproof access panels and doors.

END OF SECTION

SECTION 23 90 00

PROJECT CLOSE-OUT

PART 1 – GENERAL

A. GENERAL

1. Provisions of the General Conditions, Supplementary Conditions and Division 1 – General Requirements, and applicable provisions elsewhere in the Contract Documents that apply to the work of Divisions 21 through 23.
    a. Provisions of this Section shall also apply to all Sections of Division 21 through 23

B. WORK INCLUDED
1. The contractor shall summarize and document adherence with the requirements of the specifications for project close-out including:
    a. Copies of all Warranties
    b. Operation & Maintenance Manuals
    c. Required Tests
    d. Test & Balance Reports
    e. Project Record Documents
    f. Permit Requirements
2. The contractor shall compile a close-out manual which shall include:
    a. A list of all required test and a place for sign-off of date completed.
    b. A list of all submittals with dates of acceptance by the engineer.
    c. A schedule indicating dates for beginning testing and startup of equipment and dates of test to be witnessed by the engineer, or designated representative, as required by the specifications.
    d. Test procedures to be used for life safety systems.
    e. Project close-out check list.
3. The final close-out manual shall include the following:
    a. Test reports as required by the specifications with sign-off by the appropriate individual (engineer, architect, building official, etc.)
    b. Documentation indicating all equipment is operating properly and is fully accessible for maintenance.
    c. Copies of all warranties.
    d. Test & Balance report.
4. This section only includes the requirements for documentation of the contract documents, by the contractor, for project completion. This section does not in any way decrease the scope of any of the drawings or specifications.

C. SUBMITTALS
1. Within 90 days after notice to proceed submit a preliminary close-out manual with the following:
    a. A list of all required tests.
    b. Preliminary schedule showing major milestones for completion of mechanical/ plumbing systems.
2. Within 30 days of the first major milestone submit the completed close-out manual as described in Part 1.
3. Within 2 weeks of substantial completion submit a completed “Project Close-Out Check List” and the Final Close-Out Manual.

D. TEST AND BALANCE REPORT
1. Balancing Report: At completion of work, submit Balancing Report.

E. PROJECT RECORD DRAWINGS
   1. General: Comply with Section 01 78 39
   2. Record the following information on Drawings:
      a. Horizontal and vertical location of underground utilities.
      b. Location of internal utilities and appurtenances concealed in construction.
      c. Field changes of dimension and detail.
      d. Changes by change order or field order.
      e. Details not on original Contract Drawings.
   3. Submittal: At completion of project, deliver Project Record Documents to General Contractor.
   4. As-Constructed Drawings: As-constructed drawings shall be provided by the mechanical contractor. As-constructed drawings shall include deviations from contract documents including all RFI's, Change Orders, ASI's, and accepted PR's as outlined in item B above. Contractor shall provide information to the design team in the form of redlined hard copy drawings or redlined electronic (PDF) files.
   5. As-Built Drawings: As-built drawings shall be provided by the Design Team. Floor plan drawings shall be same scale as the contract documents and be on AutoCAD Version 2010 or later. The drawings must comply with the following:
      a. The documents (file) must be bound complete. Drawings shall be formatted the same as the contract drawings. The drawing layers, colors and line types shall be as the contract documents.
      b. Content:
         1. Limit content to the exact information that appears on the As-constructed plot.
         2. As-constructed notation with date.
      c. Perform standard file compression and recovery until file is clean.
      d. Purge all unused tables from file.
      e. Drawing layers, colors, and line type shall be same as original contract documents.
      f. Electronic File Transfer- Acceptable Media: CD Rom.
      g. Identification Label
         1. Type of file (Display or Native).
         2. Facility and project name.
         3. Consultant or sub-consultant.
         4. Contact person.
         5. Contact person's telephone number.

END OF SECTION