

SECTION 23 05 15

VARIABLE FREQUENCY DRIVES AND MOTOR STARTERS

PART 1 GENERAL

1.1 REFERENCES

- A. NEMA250
- B. IEEE 519
- C. UL 508, UL508A, UL508C
- D. NEMA ICS 7.1
- E. NFPA 70 (NEC)

1.2 SUBMITTALS

- A. Section 01 33 23 - Shop Drawings, Product Data, and Samples.
- B. Product Data: Wiring diagrams, electrical schematics, front and side views of enclosures, overall dimensions, conduit entrance locations and requirements, nameplate legends, physical layout and enclosure details. Provide data sheets showing; voltage, ratings of customer use of switching and over-current protective devices, short circuit rating, and weights.
- C. Manufacturer's Installation and Maintenance Data: Indicate application conditions and limitations of use stipulated by product testing agency specified under regulatory requirements. Include instructions for storage, handling, protection, examination, preparation, installation, and starting of drive. Document the sequence of operation, cautions and warnings, trouble shooting procedures, and spare parts lists.

1.3 DELIVERY, STORAGE, AND HANDLING

- A. Store in a clean, dry space. Maintain factory wrapping, or provide additional heavy canvas, or heavy plastic cover, to protect units from dirt, water, construction debris, and traffic.
- B. Handle carefully, in accordance of manufacturer's written instruction, to avoid damage to components, enclosure, and finish.

1.4 WARRANTY

- A. Provide warranty for 5 years from date of start up. Warranty shall include parts, and labor at factory for repair. Servicing technician on equipment shall not require factory certification to preserve warranty.

PART 2 PRODUCTS

2.1 VARIABLE FREQUENCY DRIVES

- A. Variable frequency drives which serve HVAC motors shall be Yaskawa series E7B Drive/Bypass Systems or approved equal. The VFD is to be a variable torque AC drive system designed specifically for HVAC applications in building automation, and shall include built-in features such as Network Communications, H/O/A, PI (set point control), and energy-saving functions.

1. The VFD shall include embedded serial communication for building automation protocols, including: N2, BACNET and Modbus.
2. The Touchpad Control/Operator is to be equipped with 6 LED illuminated selector buttons: Hand, Off, Auto, Drive Select, Bypass Select and Drive Test. The E7L also features 11 other status LED indicators: Control Power, Drive Ready, Drive Run, Drive Fault, Bypass Run, Motor O/L, Safety Open, Damper/BAS Interlock, Smoke Purge, Auto Transfer, and Auto Run.
3. The VFD shall include software which allows upload/download, as well as graphing and monitoring of drive parameters from a PC for ease of drive management, and shall allow settings to be recovered at any time via the User Re-initialization function.
4. Provide built-in PI feature to allow VFD to maintain set point for closed loop control of fans and pumps for pressure, flow or temperature regulation and eliminates the need for closed loop output signals from a BAS. The PI is to include feedback display, inverse, square root and differential control functions.
5. The Drive/Bypass standard inputs must include Safety Interlocks, Auto Run/Stop, Damper/BAS Interlock, Remote Transfer to Bypass, Smoke Purge, 0-10 VDC or 4-20 mA input speed signal and an RS485 communication port. The standard outputs include 3 Programmable (Form C) Relays, 1 Motor Run (Form A) Relay (all output relays rated 250 VAC, 1 Amp) and 2 programmable analog outputs (0-10 VDC or 4-20 mA). It shall also be provided with an internally mounted VFD input service disconnect to allow powering drive to allow troubleshooting while the system continues to run in bypass mode.
6. The VFD shall include a Sleep function, which will provide significant energy savings by minimizing operating hours, as well as under-torque detection designed to alert the operator to conditions such as loss of load or broken belts.
7. Energy savings control is an automatic output voltage adjustment responsive to actual motor load. Real-time energy saving is based on motor algorithms. Motor efficiency is increased by several percent. Built-in kW-hour and kW display eliminates the need for an external signal conditioner for energy monitoring.
8. When installed inside the building, the VFD shall be provided with standard NEMA 1 enclosure. If mounted outdoors, an optional NEMA 3R outdoor enclosure shall be provided.
9. Performance features for the VFD shall include: 110% overload capacity for 60 sec (150% peak); DC injection braking: at start or stop, adjustable, current limited (anti-windmilling); Adjustable accel/decel: 0.1 to 6000 sec. Critical frequency rejection: 3

- selectable, adjustable bands; Energy saving control; Torque boost: full range, automatic; Power loss ride-thru: 2 seconds; Auto restart after power loss or resettable fault, selectable, programmable; Feedback signal loss detection; Serial communication loss detection; Stationary motor auto-tuning; Sleep function; Ramp-to-stop or coast-to-stop selection; Copy keypad.
- B. Protective features to be provided shall include: Current-limited stall prevention; Cooling fan operating hours recorded; Bi-directional start into rotating motor at synchronized speed; Current-limiting DC bus fuse; Short circuit protection: Phase-phase and phase-neutral; Ground fault protection; Short circuit withstand rating: 65K RMS, 100K RMS with bus reactor; Electronic motor overload: Fault display: last 10 faults; Program security code; "Hunting" prevention logic; Input source protection (MOV's); Input/output phase loss protection
- C. Design Features shall include: 32-bit microprocessor logic; Flash upgradeable firmware; Non-volatile memory, program retention; Surface-mount devices; Displacement power factor: 0.98; Output frequency: 0.1 to 120 Hz; Frequency resolution: 0.06 Hz; Frequency regulation: 0.1%; Carrier frequency: selectable to 15 kHz; 3% DC bus reactor: 30 HP, 240 VAC; 40-60 HP, 480 VAC (optional on lower ratings); LED display; 24 VDC control logic; Transmitter/Option power supply; Input/output terminal status; Timer function: Elapsed time, Delay on start, Delay on stop; Embedded Metasys N2, APOGEE FLN, and Modbus; Volts/hertz ratio: Preset and programmable V/Hz patterns; Remote speed command: 0-10 VDC or 4-20 mA, direct or reverse-acting; Setpoint (PI) control with inverse or square root input, differential control via two feedback capability; Feedback signal: low pass filter; Speed command: bias and gain; Meter Functions: Volt, amp, kilowatt, elapsed run time, speed command; Individual Current Transformers on each output phase; UL, cUL listed and CE marked; IEC 146; Cooling tower fan, de-ice feature.
- D. VFD shall be capable of operation at the following service conditions: Ambient Temperature: -10°C to 40°C (14° F to 104° F); Humidity: 95% RH, non-condensing; Altitude: 3300 ft; higher by derate; Input voltage: +10%/-15%; Input frequency: 50/60 Hz ± 5%; 3-phase, 3-wire, phase sequence insensitive; Plenum rated (UL 1995).
- E. The VFD shall incorporate a factory mounted and wired two contactor bypass, which shall include the following features: Bypass and Drive are factory assembled, and electrically interlocked, utilizing 2 contactors with Electronic Control System; NEMA 1 metal enclosure

standard; Input disconnect switch with a lockable, through-the-door operating mechanism; Sealed Bypass Control Keypad mounted on front door with integrated Drive touchpad control; Drive Output and Bypass contactors; Bi-metallic thermal overload relay, provides motor protection in both the "drive" and "bypass" modes; 120 VAC control power transformer; Control and safety circuit terminal strip (Selectable for 120 VAC or 24 VDC input); Indicator LED's for Control Power, Drive Ready, Drive Run, Drive Selected, Drive Fault, Drive Test, Bypass Selected, Bypass Run, Motor OL, Safety Open, Damper/BAS, Auto Run, Auto Transfer, Smoke Purge, Hand Mode, Off Mode, and Auto Mode.; 3 programmable Form C contacts (250 VAC, 1 Amp) for: Motor Run, Damper/BAS, Drive Run, Hand Mode, Auto Mode, Bypass Run, Fault or 1 selectable from the drive menu; Remote Run/Stop via contact closure or serial communication; Input speed command via 0-10 VDC, 4-20 mA or serial communication; 2 Programmable analog outputs (0-10 VDC or 4-20 mA); Damper control circuit; Programmable auto transfer to bypass on drive fault; Remote transfer to bypass via contact closure; Smoke purge function via contact closure; Safety (freezestat, firestat, duct pressure, etc) interlock; Building Automation System (BAS) interlock.

- F. VFD manufacturer is responsible for all necessary labor, materials, or replacement parts required to resolve an issue with VFD-motor harmonics.

2.4 MOTOR STARTER DESCRIPTION

- A. Single Phase Starters: Starters for 115VAC single phase motors less than 1 HP shall be capable of both manual and automatic operation.
- B. Magnetic Starters: Starters for 3-phase motors shall be magnetic starters.
- C. Combination Starters: Provide combination magnetic starters for all motors requiring branch circuit protection or a line-of-sight disconnect.
- D. Manufacturers:
 - 1. ABB
 - 2. Cerus
 - 3. Emerson
 - 4. Yaskawa

2.5 SINGLE PHASE STARTER

- A. Single Phase Motor Starter Control: The single phase motor starter shall consist of a manually operated quick-make toggle mechanism lockable in the "Off" position which shall also function as the motor disconnect, the starter shall provide thermal overload protection, run status pilot light and fault pilot light. The starter must include the capability to operate in both manual and automatic control modes. In automatic mode, the starter shall have the capability to integrate with a building automation system by providing terminals for run input, run status output and fault output. All control terminals shall be integrated in the starter. At a minimum, each single phase starter shall include an interposing run relay and current sensing status output relay. Single phase motor starter shall be in a surface mount enclosure.

2.6 MAGNETIC STARTER

- A. Magnetic Motor Starters shall be enclosed in a general purpose electrical enclosure with the appropriate environmental rating.
- B. Starters shall consist of a horsepower rated magnetic contactor with a minimum of 1NO and 1NC auxiliary contacts and solid state electronic overload relay. Overload relay shall protect all three phases with a wide range current setting and trip class to allow field adjustment for specific motor FLA. Overload relay shall provide phase failure, phase loss, locked rotor and stall protection.
- C. Provide a manual reset pushbutton on the starter cover to restore normal operation after a trip or fault condition.
- D. Each starter shall include an installed 50VA control power transformer (CPT) with protected secondary. The CPT must accept the available line voltage and the control voltage shall not exceed 120V.
- E. Installed accessories shall include Hand-Off-Auto operation switch. Include LED pilot light indicators for Hand, Off, Auto, Run and Overload conditions. All pilot devices shall be water tight and dust tight.
- F. When remotely controlled by an automation system, the starter shall include remote run terminals which accept both a voltage input signal and a contact closure. The voltage run input shall accept both AC and DC signals including 24VAC, 120VAC, 24VDC and 48VDC to allow direct connection of the transistorized automation signal to the starter.
- G. In applications where the motor is interlocked with a damper or valve, the actuator control must reside within the starter enclosure. The starter must provide a voltage output to operate the actuator to open the damper or valve without closing the motor circuit. The starter will only close the motor circuit and start the motor after it has received a

contact closure from a limit or end switch confirming the damper or valve position.

- H. The starter shall provide a provision for Fireman's Override operation. When activated, the starter run the motor in any mode (Hand, Off or Auto) regardless of other inputs or lack of inputs either manual or auto. The purpose of the Fireman's Override input is to act as a smoke purge function. Fireman's Override has priority over the Emergency Shutdown input.
- I. If the starter is controlled by a fire alarm or life safety system, the starter shall include an Emergency Shutdown input which will disable the starter from operating in either Hand or Auto mode regardless of other inputs either manual or auto.

2.7 COMBINATION STARTER

- A. Enclosed combination starters shall include all of the magnetic starter requirements in addition to a disconnecting method. Acceptable disconnects include: motor circuit protectors, UL 489 circuit breakers, or a fused disconnects. All disconnects shall include a lock-out mechanism when in the off position.
- B. The Motor Circuit protector shall be a UL listed 508 current limiting manual motor starter with magnetic trip elements only. The breaker shall carry a UL 508F rating (up to 100A frame size) which provides for coordinated short circuit rating for use with the motor contactor and provides a minimum interrupting rating of 30,000 AIC for the combination starter.
- C. Fused disconnect shall be UL 98 suitable for service entrance protection. It shall accommodate time delay J-style fuses.
- D. UL 489 breaker shall include thermal and magnetic trip mechanisms.

2.8 ADDITIONAL STARTER REQUIREMENTS

- A. Must provide over/under voltage and phase monitoring capability. Monitor shall be field adjustable for both over and under voltage levels and a delay time before returning to normal operation after a trip.
- B. The starter shall provide the capability to monitor and calculate power consumption (kWh) of the motor load. Each starter shall display the calculated kW and kWh. Additionally, provide either a pulse output (kWh) or 4-20mA analog signal (kW) to the automation system to monitor the power consumption.
- C. Starter must be capable of communicating over BACnet MS/TP. At a minimum, reported points shall include starter mode, terminal input status, run/fault status, voltage, current, power factor, kW and kWh.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Install in accordance with NEMA ICS 7.1 and NFPA 70 (NEC).
- B. Install engraved phenolic label for each starter and VFD.
- C. Ground and bond device per Division 16 requirements.
- D. Starters and VFD to be provided by Mechanical Contractor and installed by Electrical Contractor.

3.2 START-UP

- A. Provide startup for each device by a factory authorized technician.

3.3 TRAINING

- A. Manufacturer Representative to provide onsite Owner training as scheduled by the Mechanical Contractor.

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SECTION 23 05 48

VIBRATION ISOLATION AND SEISMIC/WIND CONTROLS FOR HVAC PIPING AND EQUIPMENT

PART 1 GENERAL

1.1 WORK INCLUDED

- A. This section provides minimum acceptance requirements for vibration isolation and seismic/wind restraints for all heating, ventilating, and air-conditioning equipment, ductwork and piping.
- B. See schedules on drawings and this section for specific requirements for equipment.

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Seismic restraints for fire suppression systems are provided in Division 21.
- B. Vibration isolation and seismic restraints for plumbing systems are provided in Division 22.
- C. Ductwork flexible connections are specified elsewhere in Division 23.
- D. Vibration isolation and seismic restraints for electrical systems are provided in Division 26.

1.3 SUMMARY

- A. This Section includes the following:
 - 1. Vibration Isolation:
 - a. Concrete Inertia Base
 - b. Isolators
 - 1) Free Spring Floor Mounted Isolators
 - 2) Restrained Spring Floor Mounted Isolators
 - 3) Closed Mount Spring Isolators
 - c. Rubber-in-Shear Floor Mounts
 - d. Spring Hangers
 - e. Neoprene Hangers
 - f. Vibration Isolation Pads
 - g. Curb-mounted Spring Rail
 - h. Acoustic Barrier System
 - i. Flexible Connectors
 - 2. Seismic and Wind Restraints
 - a. Vibration Isolators with Integral Seismic Restraint
 - 1) Seismic Spring Floor Mounts
 - 2) Seismic Restrained Spring Isolator
 - 3) Seismic Restrained Curb-mounted Spring Rail
 - 4) Seismic Restrained Spring Isolation Roof Curb

- b. Seismic Restraint Devices:
- 1) Seismic Cable Restraints
 - 2) Hanger Rod Stiffener
 - 3) Seismic Restraint Brackets
 - 4) Seismic Snubber
 - 5) Concrete Anchor Bolts
 - 6) Grommet Washers

1.4 QUALITY ASSURANCE

- A. Unless otherwise directed by the local authority having jurisdiction, the following codes and standards will apply:
 - 1. International Building Code
 - 2. American Society of Civil Engineers 7-05
 - 3. International Mechanical Code
- B. The following guides may be used for supplemental information on typical seismic installation practices. Where a conflict exists between the guides and these construction documents, the construction documents will preside.
 - 1. Federal Emergency Management Agency manuals 412, Installing Seismic Restraints for Mechanical Equipment and 414, Installing Seismic Restraints for Ductwork and Pipe.
 - 2. Sheet Metal and Air-conditioning Contractors' National Association's Seismic Restraint Manual Guidelines for Mechanical Systems, 3rd ed., 2008
 - 3. American Society for Heating, Refrigerating and Air-conditioning Engineers' A Practical Guide to Seismic Restraint
 - 4. Manufacturers Standardization Society of the Valve and Fittings Industry MSS SP-127-2001, Bracing for Piping Systems, Seismic - Wind - Dynamic, Design, Selection, Application.

1.5 PERFORMANCE REQUIREMENTS

- A. Wind Restraint Loading:
 - 1. Basic Wind Speed: Same as structure. See structural notes.
 - 2. Building Occupancy Category: See structural notes.
 - 3. Minimum 10 lb/sq. ft. multiplied by the maximum area of the HVAC component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.
- B. Seismic Restraint Loading:
 - 1. Site Class as defined in the IBC: See Structural notes, plans, and/or specifications for requirements.
 - 2. Assigned Building Occupancy Category as defined in the IBC: See Structural notes, plans, and/or specifications for requirements.
 - a. Component Importance Factor (I_p): See Mechanical Plans for Schedule
 - b. Component Response Modification Factor (R_p): Per ASCE 7-05
 - c. Component Amplification Factor (A_p): Per ASCE 7-05
 - 3. Design Spectral Response Acceleration at Short Periods (S_{DS}): See Structural notes, plans, and/or specifications for requirements.

4. Design Spectral Response Acceleration at 1-Second Period (S_{D1}): See Structural notes, plans, and/or specifications for requirements.

1.6 SUBMITTALS

- A. Submit shop drawings for all devices specified herein and as indicated and scheduled on the drawings. Submittals shall indicate full compliance with the device specification in Part 2. Any deviation shall be specifically noted and subject to engineer approval. Submittals shall include device dimensions, placement, attachment and anchorage requirements.
- B. Provide calculations for selection of seismic/wind restraints, certified by a qualified professional engineer, licensed in the state of the project.
- C. Provide Finite Element Analysis (FEA) of all customized restraints, snubbers, and support structures such as equipment bases and roof curbs. A summary report from the analyses shall be made available to the Engineer and shall indicate compliance with the design forces for the project - including all gravity, wind and seismic loads. The report shall show locations of maximum stress and explain any allowances given for localized yielding along with safety factors.

PART 2 PRODUCTS

2.1 VIBRATION ISOLATION

- A. Manufacturers: Subject to compliance with requirements, provide products by Vibro-Acoustics (Basis of Design) or approved equal.
- B. Springs: All springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. All springs except internal nested springs shall have an outside diameter not less than 0.8 of the compressed height of the spring. Ends of springs shall be square and ground for stability. Laterally stable springs shall have k_x/k_y ratios of at least 0.9. All springs shall be fully color-coded to indicate capacity - color striping is not considered adequate.
- C. Corrosion Protection: All springs shall be powder-coated enamel. Housings shall be galvanized, powder-coated enamel, or painted with rust-resistant paint. Hot-dipped galvanized housings shall be provided as indicated on the Schedule.
- D. Concrete Inertia Base: Inertia bases shall be of welded steel construction with concrete in-fill supplied by the installing contractor on site and shall incorporate No.4 reinforcing bars, welded 12 in. maximum on centers each way.

1. Inertia bases for pumps shall be of sufficient size to accommodate supports for pipe elbows at pump suction and discharge connections.
2. Inertia bases for fans shall include motor slide rails as indicated on the Schedule.
3. The weight of each inertia base shall be at least equal to the weight of the equipment mounted thereon or sufficient to lower the center of gravity to or below the isolator support plane.
4. Inertia bases shall be a minimum of 6 in. thick.
5. Height-saving brackets or welded steel pockets shall be incorporated to ensure a 2 in. minimum clearance under each inertia base.

E. Isolators:

1. Free Spring Floor Mounted Isolators: Type FS - Free-standing, laterally stable, unhooded spring isolators with components for leveling and securing equipment. Springs shall be supported either with a neoprene cup or a metal base plate complete with a ribbed neoprene pad, minimum 0.25 in. thick, bonded to the base plate. Type FST - same as Type FS with the addition of an equipment support top plate.
2. Restrained Spring Floor Mounted Isolators: Type CSR - Laterally stable, vertically restrained spring isolators with welded steel housings and heavy top plates for supporting equipment. Springs shall be supported either with a neoprene cup or a metal base plate complete with a ribbed neoprene pad, minimum 0.25 in. thick, bonded to the base plate. Housings shall include vertically restraining limit stops. Minimum clearance around the restraining bolts and between the housing and the spring shall be 0.5 in. Top plate and restraining bolts shall be out of contact with the housing during normal operation and neoprene grommets shall be incorporated to minimize short-circuiting of restraining bolts.
3. Closed Mount Spring Isolators: Type CM - Floor mounted spring isolators with telescoping housings and bolts for leveling and securing equipment. Springs shall be supported either with a neoprene cup or a metal base plate complete with a neoprene noise isolation pad, minimum 0.25 in. thick, bonded to the base plate. Housings shall be fabricated or welded steel telescoping housings that incorporate neoprene stabilizers to minimize short circuiting and provide vertical damping.

4. Rubber-in-Shear Floor Mounts: Type RD - "Double-deflection" neoprene isolators, with neoprene-coated metal surfaces, and top and bottom surfaces ribbed. Isolators shall have bolt holes in the base.
5. Spring Hangers: Vibration isolator hanger supports with steel springs and welded steel housings. Hangers shall be designed for a minimum of 15 degree angular misalignment from vertical before support rod contacts housing; hangers serving lightweight loads 200 lbs and less may be exempt from this requirement. Provide a vertical uplift stop-washer on spring hangers for seismically restrained equipment, duct or piping.
 - a. Type SH - spring hanger isolators complete with spring, compression cup, and neoprene acoustic washer.
 - b. Type SHR - spring hanger with neoprene isolators complete with spring, compression cup, and neoprene "double-deflection" element at top of hanger.
 - c. Type SHB - spring hanger with bottom cup isolators complete with spring, compression cup, and neoprene cup under spring.
 - d. Type SHRB - spring hanger with neoprene and bottom cup isolators complete with spring, compression cup, neoprene "double-deflection" element at top of hanger, and neoprene cup under the spring.
 - e. Type PSH - precompressed spring hanger isolators complete with spring, compression cup, neoprene acoustic washer, and hardware to compress spring. Springs shall be precompressed to 2/3 rated load.
 - f. Type PSHR - precompressed spring hanger with neoprene isolators complete with spring, compression cup, neoprene "double-deflection" element at top of hanger, and hardware to compress spring. Springs shall be precompressed to 2/3 rated load.
 - g. Type PSHB - precompressed spring hanger with bottom cup isolators complete with spring, compression cup, neoprene cup under spring, and hardware to compress spring. Springs shall be precompressed to 2/3 rated load.
 - h. Type PSHRB - precompressed spring hanger with neoprene and bottom cup isolators complete with spring, compression cup, neoprene "double-deflection" element at top of hanger, neoprene cup under the spring, and hardware to compress spring. Springs shall be precompressed to 2/3 rated load.

6. Neoprene Hangers: Type NH - "Double-deflection" neoprene hanger isolators, each with an integral neoprene sleeve between hanger rod and housing. The neoprene element shall include an internal metal washer as a fail safe to prevent pull-out failure. Provide vertical uplift stopwasher on neoprene hangers for seismically restrained equipment, duct or piping.
7. Vibration Isolation Pads: Type NSN - Sandwich neoprene pad type isolators, with 3/8 in. minimum thick ribbed neoprene pads bonded to each side of a 10 ga. minimum galvanized metal plate. Isolator pads shall be selected to ensure that deflection does not exceed 20% of isolator free height.
8. Curb-mounted Spring Rail: Type RTR - Full-perimeter rail type isolator, minimum 16 ga. formed galvanized steel construction with integral spring isolators designed to fit over a roof curb and under the isolated equipment. Wind resistance shall be provided by means of resilient snubbers with a minimum clearance of 1/4 in. so as not to interfere with the spring action except in high winds. The weather seal shall consist of continuous closed cell sponge materials both above and below the base and a waterproof, flexible EPDM connection joining the outside perimeter of the upper and lower members. The rail shall be manufactured, shipped and installed as a single piece unless its size exceeds standard shipping dimensions. Shipping splits and lifting points shall be coordinated with the installing contractor. An optional acoustic barrier system shall be provided as scheduled.
9. Flexible connectors - Type SMP: Construction to be of annular corrugated stainless steel close-pitch hose with stainless steel over braid. The corrugated metal hose, braid(s), and a stainless steel ring-ferrule/band (material gauge not less than .048") must be integrally seal-welded using a 100% circumferential, full-penetration TIG weld. End fittings shall be flat-face plate steel flanges with 150# ANSI drilling and outside diameter. Fittings must be attached using a 100% circumferential TIG weld. Braided stainless steel pump connector(s) must be suitable for operating temperatures up to 850 degrees F. The rated working pressure of the braided metal hose must have a minimum 4:1 safety factor. Each braided stainless steel pump connector shall be individually leak tested using air-under-water or hydrostatic pressure. Flanged pump connectors shall be prepared for shipment using cut-to-length

spacers, securely positioned between the flanges to prevent axial compression damage and maintain the manufactured length. Spacers must be removed prior to system start up.

2.2 SEISMIC AND WIND RESTRAINTS

- A. Manufacturers: Subject to compliance with requirements, provide products by Vibro-Acoustics (Basis of Design) or approved equal.
- B. General:
1. Provide positive seismic and wind restraints on those systems and components required by the applicable building code and by the local authority having jurisdiction.
 2. Provide restraint devices as required, specified, and as scheduled for isolated and non-isolated systems and equipment. Provide calculations to determine restraint loadings for all restrained systems and equipment resulting from seismic forces.
 3. See the vibration isolation and seismic restraint schedule on the drawings for equipment specific values to be used in calculating the seismic restraint forces, including component importance factor, I_p .
- C. Vibration isolators with integral seismic restraint: Isolator housings shall be capable of withstanding the applicable design forces for the specific installation.
1. Seismic Spring Floor Mounts: Type SFS - Laterally stable, restrained spring type with support for bolting to the equipment. Springs shall be supported either with a neoprene cup or a metal base plate complete with a neoprene noise isolation pad, minimum 1/4 in. thick, bonded to the base plate. Mount shall include integral all-directional limit stops with elastomeric grommets preventing metal-to-metal contact and with minimum 1/4 in. clearance under normal operation.
 2. Seismic Restrained Spring Isolator: Type SCSR - Laterally stable, restrained spring type with housings and heavy top plates for supporting the equipment and resisting seismic and wind loading. Housings shall be of welded steel construction and include vertically restraining limit stops. Maximum clearance around the restraining bolts shall be 1/4 in. Top plate and restraining bolts shall be out of contact with the housing during normal operation and neoprene grommets shall be incorporated to minimize short-circuiting of restraining bolts.
 3. Seismic Restrained Curb-mounted Spring Rail: Type RTR w/ seismic restraint - Full-perimeter rail type, minimum 16 ga. formed

galvanized steel construction with integral spring isolators designed to fit over a roof curb and under the isolated equipment. Seismic and wind resistance shall be provided by means of wire rope assemblies and resilient snubbers with a minimum clearance of 1/8 in. so as not to interfere with the spring action under normal operation. The weather seal shall consist of continuous closed cell sponge materials both above and below the base and a waterproof, flexible neoprene connection joining the outside perimeter of the upper and lower members. The rail shall be manufactured, shipped and installed as a single piece unless its size exceeds standard shipping dimensions. Shipping splits and lifting points shall be coordinated with the installing contractor. An optional acoustic barrier package shall be provided as required and scheduled.

- D. Seismic restraint devices: Devices shall be capable of withstanding the applicable design forces for the specific installation.
1. Seismic Rated Roof Curb: Type RC w/ seismic restraint - minimum 18 ga. formed galvanized steel construction equipment curb for elevating equipment above roof. The curb shall be designed to bear directly on and attach directly to the roof structure with provisions for accommodating roof slope and maintaining equipment level. The minimum height of the curb shall be 14 in. to the top of a full-perimeter factory-attached 2x4 wood nailer. The curb shall provide continuous support for the equipment and shall withstand wind and seismic forces. Galvanized steel duct supports and flex connections shall be provided as required. The curb shall be manufactured, shipped and installed as a single piece unless its size exceeds standard shipping dimensions. Shipping splits and lifting points shall be coordinated with the installing contractor. An optional acoustic barrier package shall be provided as scheduled.
 2. Seismic Cable Restraints: Type SRK - Seismic cable sway bracing restraints shall consist of 7x19 galvanized steel aircraft cable sized to resist seismic loads with a safety factor of five (5). Cable end connections shall use heavy brackets, thimbles, and wire rope clips or compression sleeves.
 3. Hanger Rod Stiffener: Structural steel angle attached with a formed steel clamp (Type VAC) to threaded rod support. Steel angle to be provided by contractor; steel clamp to be provided by seismic restraint manufacturer.

4. Seismic Restraint Brackets: Type SRB - Formed steel brackets for securing floor-mounted equipment complete with pre-drilled holes. Brackets shall be galvanized or powder coated enamel for corrosion protection.
5. Seismic Snubber: Structural steel angle(s) with surfaces covered with ribbed neoprene pads to cushion contact with snubber. Customized snubber designs may use other structural shapes and configurations as required. Snubbers shall be designed to limit equipment motion to no more than 1/4 in. in any direction.
6. Concrete Anchor Bolts: Post-installed anchors in concrete shall be qualified for seismic restraint application in accordance with ACI 355.2.
 - a. Mechanical anchor bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications.
 - b. Adhesive Anchor Bolts: Drilled-in and capsule anchor system containing polyvinyl or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications.
7. Grommet Washers: Type GW neoprene grommet washers, 70 durometer, of sufficient size to accommodate USS standard washers, long enough to sleeve through 1/4 in. plate material, and with at least 1/8 in. thick material around the bolt hole.

PART 3 EXECUTION

3.1 GENERAL

- A. Coordinate size, doweling, and reinforcing of concrete equipment housekeeping pads and piers with vibration isolation and seismic restraint device manufacturer to ensure adequate space and prevent edge breakout failures. Pads and piers must be adequately doweled in to structural slab.
- B. Coordinate locations and sizes of structural supports with locations of vibration isolators and seismic/wind restraints (e.g., roof curbs, cooling towers, air-cooled chillers, etc.).
- C. Isolated and restrained equipment, duct and piping located on roofs must be attached to the structure. Supports (e.g., sleepers) that are not attached to the structure will not be acceptable.

- D. Restraints must transfer designed seismic/wind forces to the building structure. Attachments must be made by anchors, bolts, welds or other approved positive method. Attachments that rely on friction due to gravity shall not be approved.

3.2 VIBRATION ISOLATION

- A. Block and shim all bases level so that all ductwork, piping and electrical connections can be made to a rigid system at the proper operating level, before isolators are adjusted. Ensure that there are no rigid connections or incidental physical contacts between isolated equipment and the building structure or nearby systems.
- B. Ensure housekeeping pads have adequate space to mount equipment and isolator housings and shall also be large enough to ensure adequate edge distance for isolator anchors.
- C. Select and locate vibration isolation equipment to give uniform loading and deflection, according to weight distribution of equipment.
- D. Mount fans, as indicated on the Drawings, on structural steel vibration bases common to both fan and motor. There shall be a minimum operating clearance of 1 in. between steel bases and the structure.
- E. Mount pumps and equipment, as indicated on the Drawings, on concrete-filled inertia bases. Concrete in-fill shall be supplied by the installing contractor on site. There shall be a minimum operating clearance of 2 in. between each inertia base and its foundation.
- F. Extent of Piping Isolation:
 - 1. Isolate all piping larger than 1 in. dia. rigidly connected to vibration isolated equipment with 1 in. static deflection spring hangers at spacing intervals in accordance with the following:

<u>Pipe Diameter</u>	<u>Distance from Vibrating Equipm ent</u>
2" to 4"	50'
6" and 8"	60'
10" and larger	70'

- a. Chilled and Heating Water Piping:

- 1) Horizontal: Pipe stand floor supports shall be supported on Type CSR isolators. Suspended piping shall be supported with Type SHR isolators. The first 3 isolators shall have the same minimum static deflection as the equipment isolators, with a

maximum of 2 in. The remaining isolators shall have a minimum 1 in. static deflection.

- 2) Vertical: Piping shall be isolated from the supporting members or structure with Type FS or SHR isolators with a minimum 1 in. static deflection.
2. Spring hanger isolators shall be cut in to the hanger rods and installed after the system is filled. Alternatively, provisions must be made to ensure piping does not change height during installation and start-up.
3. Piping attached to isolated equipment with flexible connections or to air handling units with internal vibration isolators meeting the requirements of these specifications is exempt from these requirements.

G. Extent of Ductwork Isolation:

1. Provide isolation for ductwork at a distance of 80' minimum from equipment.
 - a. Suspended ductwork shall be supported with Type SHR isolators with a minimum 1 in. static deflection.
 - b. Floor-supported ductwork shall be isolated from the structure with Type FS isolators with minimum 1 in. static deflection.

H. There shall be no rigid contact of isolated piping, ductwork, or equipment with shaft walls, floor slabs, partitions, or conduits.

I. Provide height-saving brackets where recommended by the manufacturer for equipment stability, or operating height requirements.

J. Where recommended by the manufacturer, isolator base plates shall be bolted to the structure or foundation. Bolting shall incorporate neoprene bushings and washers.

K. Provide spring-loaded thrust restraints for fans and air handling units where movement under any operating condition will exceed 3/8 in.

L. Isolator hangers shall be installed with the housing a minimum of 1/4 in. below but as close to the structure as possible. Where isolator hangers would be concealed by non-accessible acoustical sub ceiling, install the hangers immediately below the sub ceiling for access.

3.3 SEISMIC RESTRAINTS

A. General:

1. All equipment, piping and ductwork shall be restrained to resist seismic forces per the applicable building code(s) as a minimum. Additional requirements specified herein are included specifically for this project.

2. Install seismic restraint devices per the manufacturer's submittals. Any deviation from the manufacturer's instructions shall be reviewed and approved by the manufacturer.
3. Attachment to structure for suspended equipment, pipe and duct: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.
4. Wall penetrations may be used as bracing locations provided the wall can provide adequate resistance without significant damage.
5. Coordinate sizes and locations of cast-in-place inserts for post-tensioned slabs with seismic restraint manufacturer.
6. Provide hanger rod stiffeners where indicated or as required to prevent buckling of rods due to seismic forces.
7. Where rigid restraints are used on equipment, ductwork or piping, support rods for the equipment, ductwork or piping at restraint locations must be supported by anchors rated for seismic use. Post-installed concrete anchors must be in accordance with ACI 355.2.
8. Ensure housekeeping pads have adequate space to mount equipment and seismic restraint devices and shall also be large enough to ensure adequate edge distance for restraint anchor bolts to avoid housekeeping pad breakout failure.

B. Concrete Anchor Bolts:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid pre- or post-tensioned tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Mechanical Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the

surface in such a manner as to avoid introduction of air pockets in the adhesive.

5. Set anchors to manufacturer's recommended torque, using a torque wrench.

C. Equipment Restraints:

1. Seismically restrain equipment as indicated on the schedule. Install fasteners, straps and brackets as required to secure the equipment.
2. As indicated on the schedule, install seismic snubbers on HVAC equipment supported by floor-mounted, non-seismic vibration isolators. Locate snubbers as close as possible to vibration isolators and attach to equipment base and supporting structure as required.
3. Install neoprene grommet washers on equipment anchor bolts where clearance between anchor and equipment support hole exceeds 1/8 in.
4. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.

D. Duct Systems:

1. Seismically restrain all ductwork listed below, using seismic cable restraints:
 - a. All ducts with cross sectional area equal to or greater than 6 ft².
 - b. Any ductwork which if it were to fail would result in damage to a piece of equipment or building function that has a component importance factor of 1.5.
 - c. All ductwork weighing more than 17 lb/ft.
2. Space lateral supports a maximum of 30 ft. o.c., and longitudinal supports a maximum of 60 ft. o.c.
3. Duct risers shall be restrained at floor penetrations every 30 ft. maximum spacing.
4. Fire damper locations may be used as restraint locations for all directions except away from the damper.
5. Brace a change of direction longer than 12 ft.
6. Install restraint cables so they do not bend across edges of adjacent equipment or building structure.
7. This specification does not allow the use of the "12-inch rule" where duct may be exempted from seismic restraint based on the

length of the support rods provided that the rods are not subjected to bending moments.

E. Piping Systems:

1. For projects with a Seismic Design Category of C, provide seismic cable restraints on the following:
 - a. All piping systems assigned a component importance factor, I_p , of 1.5 with a nominal pipe diameter greater than 2 in. or trapeze-supported piping with combined operating weight over 10 lb/ft.
2. For projects with a Seismic Design Category of D, E or F, provide seismic cable restraints on the following:
 - a. All piping greater than 3" nominal diameter.
 - b. All piping systems assigned a component importance factor, I_p , of 1.5 with a nominal pipe diameter greater than 1 in. or trapeze-supported piping with combined operating weight over 10 lb/ft.
3. This specification does not allow the use of the "12-inch rule" where pipe may be exempted from seismic restraint based on the length of the support rods.
4. Restraint spacing:
 - a. For ductile piping, space lateral supports a maximum of 40 ft. o.c., and longitudinal supports a maximum of 80 ft. o.c.
 - b. For non-ductile piping (e.g., cast iron, PVC) space lateral supports a maximum of 20 ft. o.c., and longitudinal supports a maximum of 40 ft. o.c.
 - c. For piping with hazardous material inside (e.g., natural gas, medical gas) space lateral supports a maximum of 20 ft. o.c., and longitudinal supports a maximum of 40 ft. o.c.
 - d. For pipe risers, restrain the piping at floor penetrations using the same spacing requirements as above.
5. Brace a change of direction longer than 12 ft.
6. Longitudinal restraints for single pipe supports shall be attached directly to the pipe, not to the pipe hanger.
7. For supports with multiple pipes (trapezes), secure pipes to trapeze member with clamps approved for application.
8. Piping on roller supports shall include a second roller support located on top of the pipe at each restraint location to provide vertical restraint.
9. Install restraint cables so they do not bend across edges of adjacent equipment or building structure.

10. Install flexible metal hose loops in piping which crosses building seismic joints, sized for the anticipated amount of movement.
11. Install flexible piping connectors where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment.
12. Coordinate seismic restraints with thermal expansion compensators, guides and anchor points. Thermal expansion anchor points shall be designed to accommodate seismic forces.

3.4 INSPECTION AND CERTIFICATION

- A. After installation, arrange and pay for the vibration isolation product manufacturer to visit the site to verify that the vibration isolation systems are installed and operating properly, and shall submit a certificate so stating. Verify that isolators are adjusted, with springs perpendicular to bases or housing, adjustment bolts are tightened up on equipment mountings, and hangers are not cocked.
- B. After installation, arrange and pay for the seismic restraint product manufacturer to visit the site to verify that the seismic restraint systems are installed properly, and shall submit a certificate so stating.

- - - END - - -

SECTION 23 05 93
TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Testing, adjusting, and balancing (TAB). TAB includes the following:
1. Planning systematic TAB procedures.
 2. Design Review Report.
 3. Systems Inspection report.
 4. Review Duct Air Leakage test reports generated by Project Engineer.
 5. Systems Readiness Report.
 6. Balancing air and water distribution systems; adjustment of total system to provide design performance; and testing performance of equipment and automatic controls.
 7. Balancing and adjustment of new domestic hot water recirc system.
 8. Vibration and sound measurements.
 9. Recording and reporting results.
- B. Definitions:
1. Basic TAB used in this Section: Chapter 37, "Testing, Adjusting and Balancing" of 2007 ASHRAE Handbook, "HVAC Applications".
 2. TAB: Testing, Adjusting and Balancing; the process of checking and adjusting HVAC systems to meet design objectives.
 3. AABC: Associated Air Balance Council.
 4. Hydronic Systems: Includes chilled water and heating hot water.
 5. Air Systems: Includes all outside air, supply air, return air, exhaust air and relief air systems.
 6. Flow rate tolerance: The allowable percentage variation, minus to plus, of actual flow rate from values (design) in the contract documents.

1.2 RELATED WORK

- A. Section 23 05 11, COMMON WORK RESULTS FOR HVAC: General Mechanical Requirements.
- C. Section 23 07 11, HVAC INSULATION: Piping and Equipment Insulation.
- D. Section 23 36 00, AIR TERMINAL UNITS: Terminal Units Performance.
- E. Section 23 31 00, HVAC DUCTS AND CASINGS: Duct Leakage.
- F. Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC: Controls and Instrumentation Settings.
- G. Section 23 74 13, CUSTOM CENTRAL-STATION AIR-HANDLING UNITS
- H. Section 23 34 00, HVAC FANS

- I. Section 23 21 23, HYDRONIC PUMPS
- J. Section 23 37 00, AIR OUTLETS AND INLETS
- K. Section 23 21 13, HYDRONIC PIPING
- L. Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS. Requirements for commissioning, systems readiness checklists, and training
- M. Section 23 05 12 GENERAL MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

1.3 QUALITY ASSURANCE

- A. Refer to Articles, Quality Assurance and Submittals, in Section 23 05 11, COMMON WORK RESULTS FOR HVAC, and Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.
- B. Qualifications:
 - 1. TAB Agency: The TAB agency shall be a member of the design team and shall report to and be paid by the design team and Resident Engineer.
 - 2. The TAB agency shall be a certified member of AABC certified to perform TAB service for HVAC, water balancing and vibrations and sound testing of equipment. The certification shall be maintained for the entire duration of duties specified herein. If, for any reason, the agency loses subject certification during this period, the General Contractor shall immediately notify the Resident Engineer. Any agency that has been the subject of disciplinary action by the AABC within the five years preceding Contract Award shall not be eligible to perform any work related to the TAB. All work performed in this Section and in other related Sections by the TAB agency shall be considered invalid if the TAB agency loses its certification prior to Contract completion, and the successor agency's review shows unsatisfactory work performed by the predecessor agency.
- C. Test Equipment Criteria: The instrumentation shall meet the accuracy/calibration requirements established by AABC National Standards and instrument manufacturer. Provide calibration history of the instruments to be used for test and balance purpose.
- D. Tab Criteria:
 - 1. One or more of the applicable AABC, or SMACNA publications, supplemented by ASHRAE Handbook "HVAC Applications" Chapter 36, and requirements stated herein shall be the basis for planning, procedures, and reports.

2. Flow rate tolerance: Following tolerances are allowed. For tolerances not mentioned herein follow ASHRAE Handbook "HVAC Applications", Chapter 36, as a guideline. Air Filter resistance during tests, artificially imposed if necessary, shall be at least 100 percent of manufacturer recommended change over pressure drop values for pre-filters and after-filters.
 - a. Air handling unit and all other fans, cubic feet per minute: Minus 0 percent to plus 10 percent.
 - b. Air terminal units (maximum values): Minus 2 percent to plus 10 percent.
 - c. Minimum outside air: 0 percent to plus 10 percent.
 - d. Individual room air outlets and inlets, and air flow rates not mentioned above: Minus 5 percent to plus 10 percent except if the air to a space is 100 CFM or less the tolerance would be minus 5 to plus 5 percent.
 - e. Heating hot water pumps and hot water coils: Minus 5 percent to plus 5 percent.
 - f. Chilled water pumps: Minus 0 percent to plus 5 percent.
 - g. Chilled water coils: Minus 0 percent to plus 5 percent.
3. Systems shall be adjusted for energy efficient operation as described in PART 3.
4. Typical TAB procedures and results shall be demonstrated to the Resident Engineer for one air distribution system (including all fans, three terminal units, three rooms randomly selected by the Resident Engineer) and one hydronic system (pumps and three coils) as follows:
 - a. When field TAB work begins.
 - b. During each partial final inspection and the final inspection for the project if requested by VA.

1.4 SUBMITTALS

- A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.
- B. Submit Following for Review and Approval:
 1. Design Review Report after the system layout on air and water side is completed by the Design team.
 2. Systems inspection report on equipment and installation for conformance with design.
 3. Duct Air Leakage Test Report Review Summary.

4. Systems Readiness Report.
 5. Intermediate and Final TAB reports covering flow balance and adjustments, performance tests, vibration tests and sound tests.
 6. Include in final reports uncorrected installation deficiencies noted during TAB and applicable explanatory comments on test results that differ from design requirements.
- C. Prior to request for Final or Partial Final inspection, submit completed Test and Balance report for the area.

1.5 APPLICABLE PUBLICATIONS

- A. The following publications form a part of this specification to the extent indicated by the reference thereto. In text the publications are referenced to by the acronym of the organization.
- B. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE):
2007HVAC Applications ASHRAE Handbook, Chapter 37, Testing, Adjusting, and Balancing and Chapter 47, Sound and Vibration Control
- C. Associated Air Balance Council (AABC):
2002.....AABC National Standards for Total System Balance
- D. Sheet Metal and Air Conditioning Contractors National Association (SMACNA):
3rd Edition 2002HVAC SYSTEMS Testing, Adjusting and Balancing

PART 2 - PRODUCTS

2.1 PLUGS

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

2.2 INSULATION REPAIR MATERIAL

See Section 23 07 11, HVAC INSULATION Provide for repair of insulation removed or damaged for TAB work.

PART 3 - EXECUTION

3.1 GENERAL

- A. Refer to TAB Criteria in Article, Quality Assurance.
- B. Obtain applicable contract documents and copies of approved submittals for HVAC equipment and automatic control systems.
- C. The mechanical contractor, subcontractors, and controls contractor are required to provide all labor necessary to support TAB activities.

- D. The controls contractor shall provide all hardware and most recent version of software required to access VAV controllers, unit controllers, etc.

3.2 DESIGN REVIEW REPORT

The TAB Specialist shall review the Contract Plans and specifications and advise the Resident Engineer of any design deficiencies that would prevent the HVAC systems from effectively operating in accordance with the sequence of operation specified or prevent the effective and accurate TAB of the system. The TAB Specialist shall provide a report individually listing each deficiency and the corresponding proposed corrective action necessary for proper system operation.

3.3 SYSTEMS INSPECTION REPORT

- A. Inspect equipment and installation for conformance with design.
- B. The inspection and report is to be done after air distribution equipment is on site and duct installation has begun, but well in advance of performance testing and balancing work. The purpose of the inspection is to identify and report deviations from design and ensure that systems will be ready for TAB at the appropriate time.
- C. Reports: Follow check list format developed by AABC, or SMACNA, supplemented by narrative comments, with emphasis on air handling units and fans. Check for conformance with submittals. Verify that diffuser and register sizes are correct. Check air terminal unit installation including their duct sizes and routing.

3.4 DUCT AIR LEAKAGE TEST REPORT

TAB Agency shall perform the leakage test as outlined in "Duct leakage Tests and Repairs" in Section 23 31 00, HVAC DUCTS and CASINGS for TAB agency's role and responsibilities in witnessing, recording and reporting of deficiencies.

3.5 SYSTEM READINESS REPORT

- A. The TAB Contractor shall measure existing air and water flow rates associated with existing systems utilized to serve renovated areas as indicated on drawings. Submit report of findings to resident engineer.
- B. Inspect each System to ensure that it is complete including installation and operation of controls. Submit report to RE in standard format and forms prepared and or approved by the Commissioning Agent.

- C. Verify that all items such as ductwork piping, ports, terminals, connectors, etc., that is required for TAB are installed. Provide a report to the Resident Engineer.

3.6 TAB REPORTS

- A. Submit an intermediate report for 25 percent of systems and equipment tested and balanced to establish satisfactory test results.
- B. The TAB contractor shall provide raw data immediately in writing to the Resident Engineer if there is a problem in achieving intended results before submitting a formal report.
- C. If over 20 percent of readings in the intermediate report fall outside the acceptable range, the TAB report shall be considered invalid and all contract TAB work shall be repeated and re-submitted for approval at no additional cost to the owner.
- D. Do not proceed with the remaining systems until intermediate report is approved by the Resident Engineer.

3.7 TAB PROCEDURES

- A. Tab shall be performed in accordance with the requirement of the Standard under which TAB agency is certified by AABC.
- B. General: During TAB all related system components shall be in full operation. Fan and pump rotation, motor loads and equipment vibration shall be checked and corrected as necessary before proceeding with TAB. Set controls and/or block off parts of distribution systems to simulate design operation of variable volume air or water systems for test and balance work.
- C. Coordinate TAB procedures with existing systems and any phased construction completion requirements for the project. Provide TAB reports for pre construction air and water flow rate.
- D. Air Balance and Equipment Test: Include air handling units, fans, terminal units, fan coil units, room diffusers, outlets and inlets, and computer room AC units.
 - 1. Artificially load air filters by partial blanking to produce air pressure drop of manufacturer's recommended pressure drop.
 - 2. Adjust fan speeds to provide design air flow. V-belt drives, including fixed pitch pulley requirements, are specified in Section 23 05 11, COMMON WORK RESULTS FOR.
 - 3. Test and balance systems in all specified modes of operation, including variable volume, economizer, and fire emergency modes. Verify that dampers and other controls function properly.

4. Variable air volume (VAV) systems:
 - a. Coordinate TAB, including system volumetric controls, with Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC.
 - b. Section 23 36 00, AIR TERMINAL UNITS, specifies that maximum and minimum flow rates for air terminal units (ATU) be factory set. Check and readjust ATU flow rates if necessary. Balance air distribution from ATU on full cooling maximum scheduled cubic meters per minute (cubic feet per minute). Reset room thermostats and check ATU operation from maximum to minimum cooling, to the heating mode, and back to cooling. Record and report the heating coil leaving air temperature when the ATU is in the maximum heating mode. Record and report outdoor air flow rates under all operating conditions (The test shall demonstrate that the minimum outdoor air ventilation rate shall remain constant under all operating conditions).
 - c. Adjust operating pressure control setpoint to maintain the design flow to each space with the lowest setpoint.
5. Record final measurements for air handling equipment performance data sheets.
- E. Water Balance and Equipment Test: Include circulating pumps, convertors and coils.
 1. Adjust flow rates for equipment. Set coils and evaporator to values on equipment submittals, if different from values on contract drawings.
 2. Primary-secondary (variable volume) systems: Coordinate TAB with Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC. Balance systems at design water flow and then verify that variable flow controls function as designed.
 3. Record final measurements for hydronic equipment on performance data sheets. Include entering and leaving water temperatures for heating and cooling coils, and for convertors. Include entering and leaving air temperatures (DB/WB for cooling coils) for air handling units and reheat coils. Make air and water temperature measurements at the same time.

3.8 SOUND TESTING

- A. Perform and record required sound measurements in accordance with Division 23.
 1. The Resident Engineer may designate the specific rooms to be tested.

- B. Take measurements with a calibrated sound level meter and octave band analyzer of the accuracy required by AABC.
- C. Sound reference levels, formulas and coefficients shall be according to ASHRAE Handbook, "HVAC Applications", Chapter 46, SOUND AND VIBRATION CONTROL.
- D. Determine compliance with specifications as follows:
 - 1. When sound pressure levels are specified, including the NC Criteria in Division 23:
 - a. Reduce the background noise as much as possible by shutting off unrelated audible equipment.
 - b. Measure octave band sound pressure levels with specified equipment "off."
 - c. Measure octave band sound pressure levels with specified equipment "on."
 - d. Use the DIFFERENCE in corresponding readings to determine the sound pressure due to equipment.

DIFFERENCE:	0	1	2	3	4	5 to 9	10 or More
FACTOR:	10	7	4	3	2	1	0

Sound pressure level due to equipment equals sound pressure level with equipment "on" minus FACTOR.

- e. Plot octave bands of sound pressure level due to equipment for typical rooms on a graph which also shows noise criteria (NC) curves.
- 2. When sound power levels are specified:
 - a. Perform steps 1.a. thru 1.d., as above.
 - b. For indoor equipment: Determine room attenuating effect, i.e., difference between sound power level and sound pressure level. Determined sound power level will be the sum of sound pressure level due to equipment plus the room attenuating effect.
 - c. For outdoor equipment: Use directivity factor and distance from noise source to determine distance factor, i.e., difference between sound power level and sound pressure level. Measured sound power level will be the sum of sound pressure level due to equipment plus the distance factor. Use 30 feet for sound level location.

- E. Where measured sound levels exceed specified level, the installing contractor or equipment manufacturer shall take remedial action approved by the Resident Engineer and the necessary sound tests shall be repeated.
- F. Test readings for sound testing could go higher than 15 percent if determination is made by the Resident Engineer based on the recorded sound data.

3.9 MARKING OF SETTINGS

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

3.10 IDENTIFICATION OF TEST PORTS

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

3.11 PHASING

- A. Phased Projects: Testing and Balancing Work to follow project with areas shall be completed per the project phasing. Upon completion of the project all areas shall have been tested and balanced per the contract documents.
- B. Existing Areas: Systems that serve areas outside of the project scope shall not be adversely affected. Measure existing parameters where shown to document system capacity.

3.12 COMMISSIONING

- A. Provide commissioning documentation in accordance with the requirements of Section 23 08 00 - COMMISSIONING OF HVAC SYSTEMS for all inspection, start up, and contractor testing required above and required by the System Readiness Checklist provided by the Commissioning Agent.
- B. Components provided under this section of the specification will be tested as part of a larger system. Refer to Section 23 08 00 - COMMISSIONING OF HVAC SYSTEMS and related sections for contractor responsibilities for system commissioning.

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SECTION 23 07 11
HVAC INSULATION

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Field applied insulation for thermal efficiency and condensation control for
 - 1. HVAC piping, ductwork and equipment.
- B. Definitions
 - 1. ASJ: All service jacket, white finish facing or jacket.
 - 2. Air conditioned space: Space having air temperature and/or humidity controlled by mechanical equipment.
 - 3. Cold: Equipment, ductwork or piping handling media at design temperature of 60 degrees F or below.
 - 4. Concealed: Ductwork and piping above ceilings and in chases, interstitial space, and pipe spaces.
 - 5. Exposed: Piping, ductwork, and equipment exposed to view in finished areas including mechanical and electrical equipment rooms or exposed to outdoor weather. Attics and crawl spaces where air handling units are located are considered to be mechanical rooms. Shafts, chases, interstitial spaces, unfinished attics, crawl spaces and pipe basements are not considered finished areas.
 - 6. FSK: Foil-scrim-kraft facing.
 - 7. Hot: HVAC Ductwork handling air at design temperature above 60 degrees F; HVAC equipment or piping handling media above 105 degrees F.
 - 8. Density: Pcf - pounds per cubic foot.
 - 9. Runouts: Branch pipe connections up to one-inch nominal size to fan coil units or reheat coils for terminal units.
 - 10. Thermal conductance: Heat flow rate through materials.
 - a. Flat surface: BTU per hour per square foot.
 - b. Pipe or Cylinder: BTU per hour per linear foot.
 - 11. Thermal Conductivity (k): BTU per inch thickness, per hour, per square foot, per degree F temperature difference.
 - 12. Vapor Retarder (Vapor Barrier): A material which retards the transmission (migration) of water vapor. Performance of the vapor retarder is rated in terms of permeance (perms). For the purpose of this specification, vapor retarders shall have a maximum published

- permeance of 0.1 perms and vapor barriers shall have a maximum published permeance of 0.001 perms.
13. HPS: High pressure steam 60 psig and above.
 14. HPR: High pressure steam condensate return.
 15. MPS: Medium pressure steam 16 psig thru 59 psig.
 16. MPR: Medium pressure steam condensate return.
 17. LPS: Low pressure steam 15 psig and below.
 18. HWH: Hot water heating supply.
 19. HWHR: Hot water heating return.
 20. CW: Cold water.
 21. HW: Hot water.
 22. CH: Chilled water supply.
 23. CHR: Chilled water return.

1.2 RELATED WORK

- A. Section 07 84 00, FIRESTOPPING: Mineral fiber and bond breaker behind sealant.
- B. Section 23 05 11, COMMON WORK RESULTS FOR HVAC: General mechanical requirements and items, which are common to more than one section of Division 23.
- C. Section 23 21 23, HYDRONIC PUMPS
- D. Section 23 21 13, HYDRONIC PIPING: Hot water and chilled water piping.
- E. Section 23 31 00, HVAC DUCTS AND CASINGS: Ductwork and fittings.
- F. Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS. Requirements for commissioning, systems readiness checklists, and training.

1.3 QUALITY ASSURANCE

- A. Refer to article QUALITY ASSURANCE, in Section 23 05 11, COMMON WORK RESULTS FOR HVAC.

B. Criteria:

1. Comply with NFPA 90A, particularly paragraphs 4.3.3.1 through 4.3.3.6, 4.3.10.2.6, and 5.4.6.4, parts of which are quoted as follows:

4.3.3.1 Pipe insulation and coverings, duct coverings, duct linings, vapor retarder facings, adhesives, fasteners, tapes, and supplementary materials added to air ducts, plenums, panels, and duct silencers used in duct systems, unless otherwise provided for in 4.3.3.1.1 or 4.3.3.1.2., shall have, in the form in which they are used, a maximum flame spread index of 25 without evidence of continued progressive combustion and a maximum smoke developed index of 50 when tested in accordance with NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

4.3.3.1.1 Where these products are to be applied with adhesives, they shall be tested with such adhesives applied, or the adhesives used shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when in the final dry state. (See 4.2.4.2.)

4.3.3.1.2 The flame spread and smoke developed index requirements of 4.3.3.1.1 shall not apply to air duct weatherproof coverings where they are located entirely outside of a building, do not penetrate a wall or roof, and do not create an exposure hazard.

4.3.3.2 Closure systems for use with rigid and flexible air ducts tested in accordance with UL 181, Standard for Safety Factory-Made Air Ducts and Air Connectors, shall have been tested, listed, and used in accordance with the conditions of their listings, in accordance with one of the following:

(1) UL 181A, Standard for Safety Closure Systems for Use with Rigid Air Ducts and Air Connectors

(2) UL 181B, Standard for Safety Closure Systems for Use with Flexible Air Ducts and Air Connectors

4.3.3.3 Air duct, panel, and plenum coverings and linings, and pipe insulation and coverings shall not flame, glow, smolder, or smoke when tested in accordance with a similar test for pipe covering, ASTM C 411, Standard Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation, at the temperature to which they are exposed in service.

4.3.3.3.1 In no case shall the test temperature be below 121°C (250°F).

4.3.3.4 Air duct coverings shall not extend through walls or floors that are required to be fire stopped or required to have a fire resistance rating, unless such coverings meet the requirements of 5.4.6.4.

4.3.3.5* Air duct linings shall be interrupted at fire dampers to prevent interference with the operation of devices.

4.3.3.6 Air duct coverings shall not be installed so as to conceal or prevent the use of any service opening.

4.3.10.2.6 Materials exposed to the airflow shall be noncombustible or limited combustible and have a maximum smoke developed index of 50 or comply with the following.

4.3.10.2.6.1 Electrical wires and cables and optical fiber cables shall be listed as noncombustible or limited combustible and have a maximum smoke developed index of 50 or shall be listed as having a maximum peak optical density of 0.5 or less, an average optical density of 0.15 or less, and a maximum flame spread distance of 1.5 m (5 ft) or less when tested in accordance with NFPA 262, Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces.

4.3.10.2.6.4 Optical-fiber and communication raceways shall be listed as having a maximum peak optical density of 0.5 or less, an average optical density of 0.15 or less, and a maximum flame spread distance of 5 ft or less when tested in accordance with UL 2024, Standard for Safety Optical-Fiber Cable Raceway.

4.3.10.2.6.6 Supplementary materials for air distribution systems shall be permitted when complying with the provisions of 4.3.3.

5.4.6.4 Where air ducts pass through walls, floors, or partitions that are required to have a fire resistance rating and where fire dampers are not required, the opening in the construction around the air duct shall be as follows: 1 in. average clearance on all sides

(1) Not exceeding a 1 in. average clearance on all sides.

(2) Filled solid with an approved material capable of preventing the passage of flame and hot gases sufficient to ignite cotton waste when subjected to the time-temperature fire conditions required for fire barrier penetration as specified in NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*

2. Test methods: ASTM E84, UL 723, or NFPA 255.

3. Specified k factors are at 75 degrees F mean temperature unless stated otherwise. Where optional thermal insulation material is used, select thickness to provide thermal conductance no greater than that for the specified material. For pipe, use insulation manufacturer's published heat flow tables. For domestic hot water supply and return, run out insulation and condensation control insulation, no thickness adjustment need be made.

4. All materials shall be compatible and suitable for service temperature, and shall not contribute to corrosion or otherwise attack surface to which applied in either the wet or dry state.

C. Every package or standard container of insulation or accessories delivered to the job site for use must have a manufacturer's stamp or label giving the name of the manufacturer and description of the material.

1.4 SUBMITTALS

A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.

B. Shop Drawings:

1. All information, clearly presented, shall be included to determine compliance with drawings and specifications and ASTM, federal and military specifications.

a. Insulation materials: Specify each type used and state surface burning characteristics.

b. Insulation facings and jackets: Each type used. Make it clear that white finish will be furnished for exposed ductwork, casings and equipment.

- c. Insulation accessory materials: Each type used.
- d. Manufacturer's installation and fitting fabrication instructions for flexible unicellular insulation.
- e. Make reference to applicable specification paragraph numbers for coordination.

1.5 STORAGE AND HANDLING OF MATERIAL

Store materials in clean and dry environment, pipe covering jackets shall be clean and unmarred. Place adhesives in original containers. Maintain ambient temperatures and conditions as required by printed instructions of manufacturers of adhesives, mastics and finishing cements.

1.6 APPLICABLE PUBLICATIONS

- A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by basic designation only.
- B. Federal Specifications (Fed. Spec.):
 - L-P-535E (2) - 99.....Plastic Sheet (Sheeting): Plastic Strip; Poly (Vinyl Chloride) and Poly (Vinyl Chloride - Vinyl Acetate), Rigid.
- C. Military Specifications (Mil. Spec.):
 - MIL-A-3316C (2)-90.....Adhesives, Fire-Resistant, Thermal Insulation
 - MIL-A-24179A (1)-87.....Adhesive, Flexible Unicellular-Plastic Thermal Insulation
 - MIL-C-19565C (1)-88.....Coating Compounds, Thermal Insulation, Fire-and Water-Resistant, Vapor-Barrier
 - MIL-C-20079H-87.....Cloth, Glass; Tape, Textile Glass; and Thread, Glass and Wire-Reinforced Glass
- D. American Society for Testing and Materials (ASTM):
 - A167-99 (2004).....Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
 - B209-07.....Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
 - C411-05.....Standard test method for Hot-Surface Performance of High-Temperature Thermal Insulation

- C449-07.....Standard Specification for Mineral Fiber Hydraulic-Setting Thermal Insulating and Finishing Cement
- C533-09.....Standard Specification for Calcium Silicate Block and Pipe Thermal Insulation
- C534-08.....Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form
- C547-07.....Standard Specification for Mineral Fiber pipe Insulation
- C552-07.....Standard Specification for Cellular Glass Thermal Insulation
- C553-08.....Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
- C585-09.....Standard Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System) R (1998)
- C612-10.....Standard Specification for Mineral Fiber Block and Board Thermal Insulation
- C1126-04.....Standard Specification for Faced or Unfaced Rigid Cellular Phenolic Thermal Insulation
- C1136-10.....Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation
- D1668-97a (2006).....Standard Specification for Glass Fabrics (Woven and Treated) for Roofing and Waterproofing
- E84-10.....Standard Test Method for Surface Burning Characteristics of Building Materials
- E119-09c.....Standard Test Method for Fire Tests of Building Construction and Materials
- E136-09b.....Standard Test Methods for Behavior of Materials in a Vertical Tube Furnace at 750 degrees C (1380 F)
- E. National Fire Protection Association (NFPA):
 - 90A-09.....Standard for the Installation of Air Conditioning and Ventilating Systems

- 96-08.....Standards for Ventilation Control and Fire
Protection of Commercial Cooking Operations
- 101-09.....Life Safety Code
- 251-06.....Standard methods of Tests of Fire Endurance of
Building Construction Materials
- 255-06.....Standard Method of tests of Surface Burning
Characteristics of Building Materials

F. Underwriters Laboratories, Inc (UL):

- 723.....UL Standard for Safety Test for Surface Burning
Characteristics of Building Materials with
Revision of 09/08

G. Manufacturer's Standardization Society of the Valve and Fitting
Industry (MSS):

- SP58-2009.....Pipe Hangers and Supports Materials, Design,
and Manufacture

PART 2 - PRODUCTS

2.1 MINERAL FIBER OR FIBER GLASS

- A. ASTM C547 (Molded, Heavy-Density 1000°F Insulation) Type I molded heavy-density, one piece insulation made from inorganic glass mineral wool, non-combustible.
 - 1. Thermal Conductivity: 0.23 at 75 degrees F.
 - 2. Temperature Range: 0 - 1000 degrees F.
 - 3. All Service Jacket: UL listed ASTM C1136 Type 1, factory applied, aluminum foil reinforced with glass scrim bonded to kraft paper.
- B. ASTM C553 (Blanket, Flexible) Type I, lass B-3, Density 1 pcf, k = 0.31 at 75 degrees F, for use at temperatures up to 400 degrees F with foil scrim (FSK) facing.
- C. ASTM C547 (Pipe Fitting Insulation and Preformed Pipe Insulation), Class 1, k = 0.26 at 75 degrees F, for use at temperatures up to 450 degrees F with an all service vapor retarder jacket with polyvinyl chloride premolded fitting covering.

2.2 RIGID CELLULAR PHENOLIC FOAM

- A. Preformed (molded) pipe insulation, ASTM C1126, type III, grade 1, k = 0.15 at 50 degrees F, for use at temperatures up to 250 degrees F with all service vapor retarder jacket with polyvinyl chloride premolded fitting covering.

2.3 POLYISOCYANURATE CLOSED-CELL RIGID

- A. Preformed (fabricated) pipe insulation, ASTM C591, type IV, K = 0.19 at 75 degrees F, flame spread not over 25, smoke developed not over 50, for use at temperatures up to 300 degree F with factory applied PVDC or all service vapor retarder jacket with polyvinyl chloride premolded fitting covers.

2.4 CALCIUM SILICATE

- A. Preformed pipe Insulation: ASTM C533, Type I with indicator denoting asbestos-free material.
- B. Premolded Pipe Fitting Insulation: ASTM C533, Type I with indicator denoting asbestos-free material.
- C. Equipment Insulation: ASTM C533, Type I.
- D. Characteristics:

Insulation Characteristics	
ITEMS	TYPE I
Temperature, maximum degrees F	1200
Density (dry), lb/ ft ³	14.5
Thermal conductivity: Btu in/h ft ² degrees F @ mean temperature of 200 degrees F	0.41
Surface burning characteristics: Flame spread Index, Maximum	0
Smoke Density index, Maximum	0

2.5 INSULATION FACINGS AND JACKETS

- A. Vapor Retarder, higher strength with low water permeance \leq 0.02 or less perm rating, Beach puncture 50 units for insulation facing on exposed ductwork, casings and equipment, and for pipe insulation jackets. Facings and jackets shall be all service type (ASJ) or PVDC Vapor Retarder jacketing.
- B. ASJ jacket shall be white kraft bonded to 1 mil thick aluminum foil, fiberglass reinforced, with pressure sensitive adhesive closure. Comply with ASTM C1136. Beach puncture 50 units, Suitable for painting without sizing. Jackets shall have minimum 1-1/2 inch lap on longitudinal joints and minimum 3 inch butt strip on end joints. Butt strip material

shall be same as the jacket. Lap and butt strips shall be self-sealing type with factory-applied pressure sensitive adhesive.

- C. Vapor Retarder medium strength with low water vapor permeance of 0.02 or less perm rating), Beach puncture 25 units: Foil-Scrim-Kraft (FSK) or PVDC vapor retarder jacketing type for concealed ductwork and equipment.
- D. Factory composite materials may be used provided that they have been tested and certified by the manufacturer.
- E. Pipe fitting insulation covering (jackets): Fitting covering shall be premolded to match shape of fitting and shall be polyvinyl chloride (PVC) conforming to Fed Spec L-P-335, composition A, Type II Grade GU, and Type III, minimum thickness 0.03 inches. Provide color matching vapor retarder pressure sensitive tape.
- F. Aluminum Jacket-Piping systems: ASTM B209, 3003 alloy, H-14 temper, 0.023 inch minimum thickness with locking longitudinal joints. Jackets for elbows, tees and other fittings shall be factory-fabricated to match shape of fitting and of 0.024 inch minimum thickness aluminum. Fittings shall be of same construction as straight run jackets but need not be of the same alloy. Factory-fabricated stainless steel bands shall be installed on all circumferential joints. Bands shall be 0.5 inch wide on 18 inch centers. System shall be weatherproof if utilized for outside service.

2.6 PIPE COVERING PROTECTION SADDLES

- A. Cold pipe support: Premolded pipe insulation 180 degrees (half-shells) on bottom half of pipe at supports. Material shall be cellular glass or high density Polyisocyanurate insulation of the same thickness as adjacent insulation. Density of Polyisocyanurate insulation shall be a minimum of 3.0 pcf.

Nominal Pipe Size and Accessories Material (Insert Blocks)	
Nominal Pipe Size inches	Insert Blocks inches
Up through 5	6 long
6	6 long
8, 10, 12	9 long
14, 16	12 long
18 through 24	14 long

- B. Warm or hot pipe supports: Premolded pipe insulation (180 degree half-shells) on bottom half of pipe at supports. Material shall be high density Polyisocyanurate (for temperatures up to 300 degrees F), cellular glass or calcium silicate. Insulation at supports shall have same thickness as adjacent insulation. Density of Polyisocyanurate insulation shall be a minimum of 3.0 pcf.

2.7 ADHESIVE, MASTIC, CEMENT

- A. Mil. Spec. MIL-A-3316, Class 1: Jacket and lap adhesive and protective finish coating for insulation.
- B. Mil. Spec. MIL-A-3316, Class 2: Adhesive for laps and for adhering insulation to metal surfaces.
- C. Mil. Spec. MIL-A-24179, Type II Class 1: Adhesive for installing flexible unicellular insulation and for laps and general use.
- D. Mil. Spec. MIL-C-19565, Type I: Protective finish for outdoor use.
- E. Mil. Spec. MIL-C-19565, Type I or Type II: Vapor barrier compound for indoor use.
- F. ASTM C449: Mineral fiber hydraulic-setting thermal insulating and finishing cement.
- G. Other: Insulation manufacturers' published recommendations.
- H. Apply mastic to all raw exposed edges of insulation.

2.8 MECHANICAL FASTENERS

- A. Pins, anchors: Welded pins, or metal or nylon anchors with galvanized steel-coated or fiber washer, or clips. Pin diameter shall be as recommended by the insulation manufacturer.
- B. Staples: Outward clinching galvanized steel.
- C. Wire: 18 gage soft annealed galvanized or 14 gage copper clad steel or nickel copper alloy.
- D. Bands: 0.5 inch nominal width, brass, galvanized steel, aluminum or stainless steel.

2.9 REINFORCEMENT AND FINISHES

- A. Glass fabric, open weave: ASTM D1668, Type III (resin treated) and Type I (asphalt treated).
- B. Glass fiber fitting tape: Mil. Spec MIL-C-20079, Type II, Class 1.
- C. Tape for Flexible Elastomeric Cellular Insulation: As recommended by the insulation manufacturer.
- D. Corner beads: 2 inch by 2 inch, 26 gage galvanized steel; or, 1 inch by 1 inch, 28 gage aluminum angle adhered to 2 inch by 2 inch Kraft paper.

- E. PVC fitting cover: Fed. Spec L-P-535, Composition A, 11-86 Type II, Grade GU, with Form B Mineral Fiber insert, for media temperature 40 degrees F to 250 degrees F. below 40 degrees F and above 250 degrees F. Provide double layer insert. Provide color matching vapor barrier pressure sensitive tape.

2.10 FIRESTOPPING MATERIAL

Other than pipe and duct insulation, refer to Section 07 84 00
FIRESTOPPING.

2.11 FLAME AND SMOKE

Unless shown otherwise all assembled systems shall meet flame spread 25 and smoke developed 50 rating as developed under ASTM, NFPA and UL standards and specifications. See paragraph 1.3 "Quality Assurance".

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

- A. Required pressure tests of duct and piping joints and connections shall be completed and the work approved by the Resident Engineer for application of insulation. Surface shall be clean and dry with all foreign materials, such as dirt, oil, loose scale and rust removed.
- B. Except for specific exceptions, insulate entire specified equipment, piping (pipe, fittings, valves, accessories), and duct systems. Insulate each pipe and duct individually. Do not use scrap pieces of insulation where a full length section will fit.
- C. Where removal of insulation of piping, ductwork and equipment is required to comply with Section 02 82 11, TRADITIONAL ASBESTOS ABATEMENT and Section 02 82 13.13, GLOVEBAG ASBESTOS ABATEMENT, such areas shall be reinsulated to comply with this specification.
- D. Insulation materials shall be installed in a first class manner with smooth and even surfaces, with jackets and facings drawn tight and smoothly cemented down at all laps. Insulation shall be continuous through all sleeves and openings, except at fire dampers and duct heaters (NFPA 90A). Vapor retarders shall be continuous and uninterrupted throughout systems with operating temperature 60 degrees F and below. Lap and seal vapor retarder over ends and exposed edges of insulation. Anchors, supports and other metal projections through insulation on cold surfaces shall be insulated and vapor sealed for a minimum length of 6 inches.

- E. Install vapor stops at all insulation terminations on either side of valves, pumps and equipment and particularly in straight lengths of pipe insulation.
- F. Construct insulation on parts of equipment such as chilled water pumps and heads of chillers, convertors and heat exchangers that must be opened periodically for maintenance or repair, so insulation can be removed and replaced without damage. Install insulation with bolted 20 gage galvanized steel or aluminum covers as complete units, or in sections, with all necessary supports, and split to coincide with flange/split of the equipment.
- G. Insulation on hot piping and equipment shall be terminated square at items not to be insulated, access openings and nameplates. Cover all exposed raw insulation with white sealer or jacket material.
- H. Protect all insulations outside of buildings with aluminum jacket using lock joint or other approved system for a continuous weather tight system. Access doors and other items requiring maintenance or access shall be removable and sealable.
- I. HVAC work not to be insulated:
 - 1. Relief air ducts (Economizer cycle exhaust air).
 - 2. Exhaust air ducts and plenums, and ventilation exhaust air shafts.
 - 3. Equipment: Expansion tanks, flash tanks, hot water pumps.
 - 4. In hot piping: Unions, flexible connectors, control valves, safety valves and discharge vent piping, vacuum breakers, thermostatic vent valves, and steam traps. Insulate piping to within approximately 3 inches of uninsulated items.
 - 5. Pipes, valves and fittings:
 - a. Tank drains
 - b. Vents-tank, safety and back pressure valves except protective.
 - c. Threaded valves
 - d. Check valves
 - e. Unions
 - f. Orifice flanges
 - g. Dielectric flanges and unions
 - h. Pressure transmission to gages
 - i. Piping in control panels
 - j. Tube cleaning piping
 - 6. Equipment:
 - a. Pumps-inlet to outlet

- b. Safety valves
- c. Chemical feeders
- e. All nameplates
- 4. Specialties:
 - a. Control valves-water and steam
 - b. Strainers
 - c. Expansion bellows
 - d. Flexible connectors
- J. Apply insulation materials subject to the manufacturer's recommended temperature limits. Apply adhesives, mastic and coatings at the manufacturer's recommended minimum coverage.
- K. Elbows, flanges and other fittings shall be insulated with the same material as is used on the pipe straights. The elbow / fitting insulation shall be field-fabricated, mitered or factory prefabricated to the necessary size and shape to fit on the elbow / fitting. Use of polyurethane spray-foam to fill a PVC elbow jacket is prohibited on cold applications.
- M. Firestop Pipe and Duct insulation:
 - 1. Provide firestopping insulation at fire and smoke barriers through penetrations. Fire stopping insulation shall be UL listed as defines in Section 07 84 00, FIRESTOPPING.
 - 2. Pipe and duct penetrations requiring fire stop insulation including, but not limited to the following:
 - a. Pipe risers through floors
 - b. Pipe or duct chase walls and floors
 - c. Smoke partitions
 - d. Fire partitions
- N. Provide metal jackets for all outdoor piping.
- O. Provide vapor barrier jackets over insulation as follows:
 - 1. All piping and ductwork exposed to outdoor weather.
 - 2. All interior piping and ducts conveying fluids below ambient air temperature.

3.2 INSULATION INSTALLATION

- A. Flexible Mineral Fiber Blanket:
 - 1. Adhere insulation to metal with 3 inches wide strips of insulation bonding adhesive at 8 inches on center all around duct. Additionally secure insulation to bottom of ducts exceeding 24 inches in width with pins welded or adhered on 18 inch centers. Secure washers on

- pins. Butt insulation edges and seal joints with laps and butt strips. Staples may be used to assist in securing insulation. Seal all vapor retarder penetrations with mastic. Sagging duct insulation will not be acceptable. Install firestop duct insulation where required.
2. Supply air ductwork to be insulated includes main and branch ducts from AHU discharge to room supply outlets, and the bodies of ceiling outlets to prevent condensation. Insulate sound attenuator units, coil casings and damper frames. To prevent condensation insulate trapeze type supports and angle iron hangers for flat oval ducts that are in direct contact with metal duct.
- B. Molded Mineral Fiber Pipe and Tubing Covering:
1. Fit insulation to pipe or duct, aligning longitudinal joints. Seal longitudinal joint laps and circumferential butt strips by rubbing hard with a nylon sealing tool to assure a positive seal. Staples may be used to assist in securing insulation. Seal all vapor retarder penetrations on cold piping with a generous application of vapor barrier mastic. Provide inserts and install with metal insulation shields at outside pipe supports. Install freeze protection insulation over heating cable.
- C. Rigid Cellular Phenolic Foam:
1. Rigid closed cell phenolic insulation may be provided for piping, ductwork and equipment for temperatures up to 250 degrees F.
 2. Note the NFPA 90A burning characteristics requirements of 25/50 in paragraph 1.3.B
 3. Provide secure attachment facilities such as welding pins.
 4. Apply insulation with joints tightly drawn together
 5. Apply adhesives, coverings, neatly finished at fittings, and valves.
 6. Final installation shall be smooth, tight, neatly finished at all edges.
- D. Polyisocyanurate Closed-Cell Rigid Insulation:
1. Polyisocyanurate closed-cell rigid insulation (PIR) may be provided for exterior piping, equipment and ductwork for temperature up to 300 degree F.
 2. Install insulation, vapor barrier and jacketing per manufacturer's recommendations. Particular attention should be paid to recommendations for joint staggering, adhesive application, external

- hanger design, expansion/contraction joint design and spacing and vapor barrier integrity.
3. Install insulation with all joints tightly butted (except expansion joints in hot applications).
 4. If insulation thickness exceeds 2.5 inches, install as a double layer system with longitudinal (lap) and butt joint staggering as recommended by manufacturer.
 5. For cold applications, vapor barrier shall be installed in a continuous manner. No staples, rivets, screws or any other attachment device capable of penetrating the vapor barrier shall be used to attach the vapor barrier or jacketing. No wire ties capable of penetrating the vapor barrier shall be used to hold the insulation in place. Banding shall be used to attach PVC or metal jacketing.
 6. Elbows, flanges and other fittings shall be insulated with the same material as is used on the pipe straights. The elbow/ fitting insulation shall be field-fabricated, mitered or factory prefabricated to the necessary size and shape to fit on the elbow/ fitting. Use of polyurethane spray-foam to fill PVC elbow jacket is prohibited on cold applications.
 7. For cold applications, the vapor barrier on elbows/fittings shall be either mastic-fabric-mastic or 2 mil thick PVDC vapor barrier adhesive tape.
 8. All PVC and metal jacketing shall be installed so as to naturally shed water. Joints shall point down and shall be sealed with either adhesive or caulking (except for periodic slip joints).
 9. Note the NFPA 90A burning characteristic requirements of 25/50 in paragraph 1.3B. Refer to paragraph 3.1 for items not to be insulated.
- E. Calcium Silicate Installation:
1. At pipe supports, weld pipe covering protection saddles to pipe, except where MS-SP58, type 3 pipe clamps are utilized.
 2. Insulation shall be firmly applied, joints butted tightly, mechanically fastened by stainless steel wires on 300 mm (12 inch) centers.
 3. At support points, fill and thoroughly pack space between pipes covering protective saddle bearing area.
 4. Terminate insulation and jacket hard and tight at anchor points.

5. Terminate insulation at piping facilities not insulated with a 45 degree chamfered section of insulating and finishing cement covered with jacket.
6. On calcium silicate, insulated flanged fittings, strainers and valves with sections of pipe insulation cut, fitted and arranged neatly and firmly wired in place. Fill all cracks, voids and coat outer surface with insulating cement. Install jacket. Provide similar construction on welded and threaded fittings on calcium silicate systems.
7. Insulate valve bonnet up to valve side of bonnet flange to permit bonnet flange removal without disturbing insulation.
8. Do not insulate basket removal flanges on strainers.

3.3 COMMISSIONING

- A. Provide commissioning documentation in accordance with the requirements of section 23 08 00 - COMMISSIONING OF HVAC SYSTEMS for all inspection, start up, and contractor testing required above and required by the System Readiness Checklist provided by the Commissioning Agent.
- B. Components provided under this section of the specification will be tested as part of a larger system. Refer to section 23 08 00 - COMMISSIONING OF HVAC SYSTEMS and related sections for contractor responsibilities for system commissioning.

3.4 PIPE INSULATION SCHEDULE

Provide insulation for piping systems as scheduled below:

Insulation Thickness Inches					
		Nominal Pipe Size Inches			
Operating Temperature Range/Service	Insulation Material	Less than 1	1 - 1¼	1½ - 3	4 and Above
Steam - All Pressures Condensate Return	Calcium Silicate	4	5	6	6
Steam - All Pressures Condensate Return	1000 °F Insulation	2.5	2.5	3.0	3.0
100-200 degrees F (HWH, HWHR)	Mineral Fiber (Above ground piping only)	1.5	1.5	2.0	2.0
40-60 degrees F (CH, CHR)	Rigid Cellular Phenolic Foam	1.5	1.5	1.5	1.5

40-60 degrees F (CH, CHR)	Polyiso- cyanurate Closed-Cell Rigid (Exterior Locations only)*	1.5	1.5	1.5	1.5
Supply ductwork - interior	Mineral Fiber Blanket	All sizes = 2"			
Return ductwork - interior	Mineral Fiber Blanket	All sizes = 1"			
Exhaust ductwork - interior within 10 ft or exterior	Mineral Fiber Blanket	All sizes = 1"			

*Install metal jacketing.

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SECTION 23 08 00
COMMISSIONING OF HVAC SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The requirements of this Section apply to all sections of Division 23.
- B. This project will have selected building systems commissioned. The complete list of equipment and systems to be commissioned are specified in Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS. The commissioning process, which the Contractor is responsible to execute, is defined in Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS. A Commissioning Agent (CxA) appointed by the Department of Veterans Affairs and design team will manage the commissioning process.

1.2 RELATED WORK

- A. Section 01 00 00 GENERAL REQUIREMENTS.
- B. Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS.
- C. Section 01 33 23 SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.

1.3 SUMMARY

- A. This Section includes requirements for commissioning the HVAC systems, subsystems and equipment. This Section supplements the general requirements specified in Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS.
- B. The mechanical contractor, subcontractors, and controls contractor are required to provide all labor necessary to support commissioning activities.
- C. Refer to Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS for more specifics regarding processes and procedures as well as roles and responsibilities for all Commissioning Team members.

1.4 DEFINITIONS

- A. Refer to Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS for definitions.

1.5 COMMISSIONED SYSTEMS

- A. Commissioning of a system or systems specified in this Division is part of the construction process. Documentation and testing of these systems, as well as training of the VA's Operation and Maintenance personnel, is required in cooperation with the VA and the Commissioning Agent.
- B. The following HVAC systems will be commissioned:
 - 1. Air Handling Systems (including terminal units)

2. Air Handling Systems (Fans, motors, Variable Speed Drives, cooling coils and control valves, heating coils and control valves, filters, dampers, safeties such as smoke detectors or freezestats and damper end switches, controls, gages, and vibration isolation).
3. Heating Hot Water Systems (Converters, controls, instrumentation and gages, heating water pumps and motors, and Variable Speed Drives).
4. Chilled Water Systems (Chilled water pumps and motors, Variable Speed Drives, controls, instrumentation and safeties, isolation valves, and blending valves).
5. Exhaust Fans (Fan, motor, Variable Speed Drives, controls and safeties).
6. Direct Digital Control System (BACnet or similar Local Area Network (LAN), Operator Work Station hardware and software, building controller hardware and software, terminal unit controller hardware and software, all sequences of operation, system accuracy and response time).
7. Room Pressurization Equipment (Pressure sensors, terminal units/dampers, and controls and alarms).
8. HVAC Water Treatment Systems (Closed circuits - including shot feeders and final water analysis).

1.6 SUBMITTALS

- A. The commissioning process requires review of selected Submittals. The Commissioning Agent will provide a list of submittals that will be reviewed by the Commissioning Agent. This list will be reviewed and approved by the VA prior to forwarding to the Contractor. Refer to Section 01 33 23 SHOP DRAWINGS, PRODUCT DATA, and SAMPLES for further details.
- B. The commissioning process requires Submittal review simultaneously with engineering review. Specific submittal requirements related to the commissioning process are specified in Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.1 PRE-FUNCTIONAL CHECKLISTS

A. The Contractor shall complete Pre-Functional Checklists to verify systems, subsystems, and equipment installation is complete and systems are ready for Systems Functional Performance Testing. The Commissioning Agent will prepare Pre-Functional Checklists to be used to document equipment installation. The Contractor shall complete the checklists. Completed checklists shall be submitted to the VA and to the Commissioning Agent for review. The Commissioning Agent may spot check a sample of completed checklists. If the Commissioning Agent determines that the information provided on the checklist is not accurate, the Commissioning Agent will return the marked-up checklist to the Contractor for correction and resubmission. If the Commissioning Agent determines that a significant number of completed checklists for similar equipment are not accurate, the Commissioning Agent will select a broader sample of checklists for review. If the Commissioning Agent determines that a significant number of the broader sample of checklists is also inaccurate, all the checklists for the type of equipment will be returned to the Contractor for correction and resubmission. Refer to SECTION 01 91 00 GENERAL COMMISSIONING REQUIREMENTS for submittal requirements for Pre-Functional Checklists, Equipment Startup Reports, and other commissioning documents.

3.2 CONTRACTORS TESTS

A. Contractor tests as required by other sections of Division 23 shall be scheduled and documented in accordance with Section 01 00 00 GENERAL REQUIREMENTS. The Commissioning Agent will witness selected Contractor tests. Contractor tests shall be completed prior to scheduling Systems Functional Performance Testing.

3.3 SYSTEMS FUNCTIONAL PERFORMANCE TESTING

A. The Commissioning Process includes Systems Functional Performance Testing that is intended to test systems functional performance under steady state conditions, to test system reaction to changes in operating conditions, and system performance under emergency conditions. The Commissioning Agent will prepare detailed Systems Functional Performance Test procedures for review and approval by the Resident Engineer. The Contractor shall review and comment on the tests prior to approval. The Contractor shall provide the required labor, materials, and test equipment identified in the test procedure

to perform the tests. The Commissioning Agent will witness and document the testing. The Contractor shall sign the test reports to verify tests were performed. See Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS, for additional details.

3.4 TRAINING OF VA PERSONNEL

- A. Training of the VA's operation and maintenance personnel is required in cooperation with the Resident Engineer and Commissioning Agent. Provide competent, factory authorized personnel to provide instruction to operation and maintenance personnel concerning the location, operation, and troubleshooting of the installed systems. The instruction shall be scheduled in coordination with the Resident Engineer after submission and approval of formal training plans. Refer to Section 01 91 00 GENERAL COMMISSIONING REQUIREMENTS and Division 23 Sections for additional Contractor training requirements.

----- END -----

SECTION 23 09 23
DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 DESCRIPTION

- A. All labor and materials for the DDC control system shall be by Johnson Controls. All new controls shall be fully integrated with the existing Johnson Controls front end workstation.
- B. Provide (a) direct-digital control system(s) as indicated on the project documents, point list, interoperability tables, drawings and as described in these specifications. Include a complete and working direct-digital control system. Include all engineering, programming, controls and installation materials, installation labor, commissioning and start-up, training, final project documentation and warranty.
 1. The direct-digital control system(s) shall consist of high-speed, peer-to-peer network of DDC controllers. Provide full integration with the existing Johnson Controls front end workstation.
 2. The direct-digital control system(s) shall be native BACnet. All new workstations, controllers, devices and components shall be listed by BACnet Testing Laboratories. All new controllers, devices and components shall be accessible 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 and specifically requested otherwise by the VA.
 3. 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.
 4. The control systems shall be designed such that each mechanical system shall operate under stand-alone mode. The contractor 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 other controller, the control system shall continue to operate independently. Failure of the front end workstation shall have no effect on the field controllers, including those involved with global strategies.

C. Some products are furnished but not installed by the contractor administered by this Section of the technical specifications. The contractor administered by this Section of the technical specifications shall formally coordinate in writing and receive from other contractors formal acknowledgements in writing prior to submission the installation of the products. These products include the following:

1. Control valves.
2. Flow switches.
3. Flow meters.
4. Sensor wells and sockets in piping.
5. Unit controllers. (VAV, AHU, pumps, etc.).

D. Some products are not provided by, but are nevertheless integrated with the work executed by, the contractor administered by this Section of the technical specifications. The contractor administered by this Section of the technical specifications shall formally coordinate in writing and receive from other contractors formal acknowledgements in writing prior to submission the particulars of the products. These products include the following:

1. Fire alarm systems. If zoned fire alarm is required by the project-specific requirements, this interface shall require multiple relays, which are provided and installed by the fire alarm system contractor, to be monitored.
2. Terminal units' velocity sensors
3. Variable frequency drives. These controls, if not native BACnet, will require a BACnet Gateway.

E. Responsibility Table:

Work/Item/System	Furnish	Install	Low Voltage Wiring	Line Power
Control system low voltage and communication wiring	BMS	BMS	BMS	N/A
Terminal units	23	23	BMS	26
Controllers for terminal	BMS	BMS	BMS	26

Work/Item/System	Furnish	Install	Low Voltage Wiring	Line Power
units, AHU, etc.				
Controls, conduits and raceway	BMS	BMS	N/A	N/A
Automatic dampers (not furnished with equipment)	23	23	N/A	N/A
Automatic damper actuators	BMS	BMS	BMS	26
Manual valves	23	23	N/A	N/A
Hydronic control valves	BMS	23	BMS	N/A
Thermowells, diff press sensor	BMS	23	BMS	N/A
Current Switches	BMS	BMS	BMS	N/A
Control Relays	BMS	BMS	BMS	26
All control system nodes, equipment, housings, enclosures and panels.	BMS	BMS	BMS	26
Duct detectors	26	26	26	N/A
Fire/Smoke Dampers	23	23	26	26
Smoke Dampers	23	23	26	26
Fire Dampers	23	23	N/A	N/A
VFDs / Starters	23	26	BMS	26
Fire Alarm shutdown relay interlock wiring	26	26	26	26
Control system monitoring of fire alarm smoke control relay	26	26	BMS	26
Fire-fighter's smoke control station	26	26	26	26

- F. This facility's existing direct-digital control system is manufactured by Johnson Controls. The contractor administered by this Section of the technical specifications shall observe the capabilities, communication network, services, spare capacity of the existing control system and its front end workstation prior to beginning work.
- G. The controls contractor shall provide all labor necessary to support TAB and Cx activities. The controls contractor shall provide to TAB agent all hardware and most recent version of software required to access VAV controllers, unit controllers, etc.

H. The direct-digital control system shall start and stop equipment, move (position) damper actuators and valve actuators, and vary speed of equipment to execute the mission of the control system. Use electricity as the motive force for all damper and valve actuators.

1.2 RELATED WORK

- A. Section 21 05 11, Common Work Results for Fire Suppression.
- B. Section 23 21 13, Hydronic Piping.
- C. Section 23 31 00, HVAC Ducts and Casings.
- D. Section 23 36 00, Air Terminal Units.
- E. Section 23 74 13, Custom Central-Station Air-Handling Units.
- F. Section 26 05 11, Requirements for Electrical Installations.
- G. Section 26 05 26, Grounding and Bonding for Electrical Systems.
- H. Section 26 05 33, Raceway and Boxes for Electrical Systems.
- I. Section 26 27 26, Wiring Devices.
- J. Section 27 15 00, Communications Horizontal Cabling
- K. Section 28 31 00, Fire Detection and Alarm.

1.3 DEFINITION

- A. Algorithm: A logical procedure for solving a recurrent mathematical problem; A prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps.
- B. ARCNET: ANSI/ATA 878.1 - Attached Resource Computer Network. ARCNET is a deterministic LAN technology; meaning it's possible to determine the maximum delay before a device is able to transmit a message.
- C. Analog: A continuously varying signal value (e.g., temperature, current, velocity etc).
- D. BACnet: A Data Communication Protocol for Building Automation and Control Networks, ANSI/ASHRAE Standard 135. This communications protocol allows diverse building automation devices to communicate data over and services over a network.
- E. BACnet/IP: Annex J of Standard 135. It defines and allows for using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP sub-networks that share the same BACnet network number.
- F. BACnet Internetwork: Two or more BACnet networks connected with routers. The two networks may sue different LAN technologies.
- G. BACnet Network: One or more BACnet segments that have the same network address and are interconnected by bridges at the physical and data link layers.

- H. BACnet Segment: One or more physical segments of BACnet devices on a BACnet network, connected at the physical layer by repeaters.
- I. BACnet Broadcast Management Device (BBMD): A communications device which broadcasts BACnet messages to all BACnet/IP devices and other BBMDs connected to the same BACnet/IP network.
- J. BACnet Interoperability Building Blocks (BIBBs): BACnet Interoperability Building Blocks (BIBBs) are collections of one or more BACnet services. These are prescribed in terms of an "A" and a "B" device. Both of these devices are nodes on a BACnet internetwork.
- K. BACnet Testing Laboratories (BTL). The organization responsible for testing products for compliance with the BACnet standard, operated under the direction of BACnet International.
- L. Baud: It is a signal change in a communication link. One signal change can represent one or more bits of information depending on type of transmission scheme. Simple peripheral communication is normally one bit per Baud. (e.g., Baud rate = 78,000 Baud/sec is 78,000 bits/sec, if one signal change = 1 bit).
- M. Binary: A two-state system where a high signal level represents an "ON" condition and an "OFF" condition is represented by a low signal level.
- N. BMP or bmp: Suffix, computerized image file, used after the period in a DOS-based computer file to show that the file is an image stored as a series of pixels.
- O. Bus Topology: A network topology that physically interconnects workstations and network devices in parallel on a network segment.
- P. Control Unit (CU): Generic term for any controlling unit, stand-alone, microprocessor based, digital controller residing on secondary LAN or Primary LAN, used for local controls or global controls
- Q. Deadband: A temperature range over which no heating or cooling is supplied, i.e., 72-78 degrees F, as opposed to a single point change over or overlap).
- R. Device: a control system component that contains a BACnet Device Object and uses BACnet to communicate with other devices.
- S. Device Object: Every BACnet device requires one Device Object, whose properties represent the network visible properties of that device. Every Device Object requires a unique Object Identifier number on the BACnet internetwork. This number is often referred to as the device instance.

- T. Device Profile: A specific group of services describing BACnet capabilities of a device, as defined in ASHRAE Standard 135-2008, Annex L. Standard device profiles include BACnet Operator Workstations (B-OWS), BACnet Building Controllers (B-BC), BACnet Advanced Application Controllers (B-AAC), BACnet Application Specific Controllers (B-ASC), BACnet Smart Actuator (B-SA), and BACnet Smart Sensor (B-SS). Each device used in new construction is required to have a PICS statement listing which service and BIBBs are supported by the device.
- U. Diagnostic Program: A software test program, which is used to detect and report system or peripheral malfunctions and failures. Generally, this system is performed at the initial startup of the system.
- V. Direct Digital Control (DDC): Microprocessor based control including Analog/Digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices in order to achieve a set of predefined conditions.
- W. Distributed Control System: A system in which the processing of system data is decentralized and control decisions can and are made at the subsystem level. System operational programs and information are provided to the remote subsystems and status is reported back to the Engineering Control Center. Upon the loss of communication with the Engineering Control center, the subsystems shall be capable of operating in a stand-alone mode using the last best available data.
- X. Download: The electronic transfer of programs and data files from a central computer or operation workstation with secondary memory devices to remote computers in a network (distributed) system.
- Y. DXF: An AutoCAD 2-D graphics file format. Many CAD systems import and export the DXF format for graphics interchange.
- Z. Electrical Control: A control circuit that operates on line or low voltage and uses a mechanical means, such as a temperature sensitive bimetal or bellows, to perform control functions, such as actuating a switch or positioning a potentiometer.
- AA. Electronic Control: A control circuit that operates on low voltage and uses a solid-state components to amplify input signals and perform control functions, such as operating a relay or providing an output signal to position an actuator.

- BB. Engineering Control Center (ECC): The centralized control point for the intelligent control network. The ECC comprises of personal computer and connected devices to form a single workstation.
- CC. Ethernet: A trademark for a system for exchanging messages between computers on a local area network using coaxial, fiber optic, or twisted-pair cables.
- DD. Firmware: Firmware is software programmed into read only memory (ROM) chips. Software may not be changed without physically altering the chip.
- EE. Gateway: Communication hardware connecting two or more different protocols. It translates one protocol into equivalent concepts for the other protocol. In BACnet applications, a gateway has BACnet on one side and non-BACnet (usually proprietary) protocols on the other side.
- FF. GIF: Abbreviation of Graphic interchange format.
- GG. Graphic Program (GP): Program used to produce images of air handler systems, fans, chillers, pumps, and building spaces. These images can be animated and/or color-coded to indicate operation of the equipment.
- HH. Graphic Sequence of Operation: It is a graphical representation of the sequence of operation, showing all inputs and output logical blocks.
- II. I/O Unit: The section of a digital control system through which information is received and transmitted. I/O refers to analog input (AI, digital input (DI), analog output (AO) and digital output (DO). Analog signals are continuous and represent temperature, pressure, flow rate etc, whereas digital signals convert electronic signals to digital pulses (values), represent motor status, filter status, on-off equipment etc.
- JJ. I/P: a method for conveying and routing packets of information over LAN paths. User Datagram Protocol (UDP) conveys information to "sockets" without confirmation of receipt. Transmission Control Protocol (TCP) establishes "sessions", which have end-to-end confirmation and guaranteed sequence of delivery.
- KK. JPEG: A standardized image compression mechanism stands for Joint Photographic Experts Group, the original name of the committee that wrote the standard.
- LL. Local Area Network (LAN): A communication bus that interconnects operator workstation and digital controllers for peer-to-peer communications, sharing resources and exchanging information.

- MM. Network Repeater: A device that receives data packet from one network and rebroadcasts to another network. No routing information is added to the protocol.
- NN. MS/TP: Master-slave/token-passing (ISO/IEC 8802, Part 3). It is not an acceptable LAN option for VA health-care facilities. It uses twisted-pair wiring for relatively low speed and low cost communication.
- OO. Native BACnet Device: A device that uses BACnet as its primary method of communication with other BACnet devices without intermediary gateways. A system that uses native BACnet devices at all levels is a native BACnet system.
- PP. Network Number: A site-specific number assigned to each network segment to identify for routing. This network number must be unique throughout the BACnet internetwork.
- QQ. Object: The concept of organizing BACnet information into standard components with various associated properties. Examples include analog input objects and binary output objects.
- RR. Object Identifier: An object property used to identify the object, including object type and instance. Object Identifiers must be unique within a device.
- SS. Object Properties: Attributes of an object. Examples include present value and high limit properties of an analog input object. Properties are defined in ASHRAE 135; some are optional and some are required. Objects are controlled by reading from and writing to object properties.
- TT. Operating system (OS): Software, which controls the execution of computer application programs.
- UU. PCX: File type for an image file. When photographs are scanned onto a personal computer they can be saved as PCX files and viewed or changed by a special application program as Photo Shop.
- VV. Peripheral: Different components that make the control system function as one unit. Peripherals include monitor, printer, and I/O unit.
- WW. Peer-to-Peer: A networking architecture that treats all network stations as equal partners- any device can initiate and respond to communication with other devices.
- XX. PICS: Protocol Implementation Conformance Statement, describing the BACnet capabilities of a device. All BACnet devices have published PICS.

YY. PID: Proportional, integral, and derivative control, used to control modulating equipment to maintain a setpoint.

ZZ. Repeater: A network component that connects two or more physical segments at the physical layer.

AAA. Router: a component that joins together two or more networks using different LAN technologies. Examples include joining a BACnet Ethernet LAN to a BACnet MS/TP LAN.

BBB. Sensors: devices measuring state points or flows, which are then transmitted back to the DDC system.

CCC. Thermostats : devices measuring temperatures, which are used in control of standalone or unitary systems and equipment not attached to the DDC system.

1.4 QUALITY ASSURANCE

A. Criteria:

1. Single Source Responsibility of subcontractor: The Controls Contractor shall provide hardware and software required under this Section. The controls subcontractor shall be responsible for the complete design, installation, and commissioning of the system. The controls subcontractor shall be Johnson Controls.
2. Equipment and Materials: Equipment and materials shall be cataloged products of manufacturers regularly engaged in production and installation of HVAC control systems. Products shall be manufacturer's latest standard design and have been tested and proven in actual use.
3. The controls subcontractor shall have in-place facility within 50 miles with technical staff, spare parts inventory for the next five (5) years, and necessary test and diagnostic equipment to support the control systems.
4. The controls subcontractor shall have minimum of three years experience in design and installation of building automation systems similar in performance to those specified in this Section. Provide evidence of experience by submitting resumes of the project manager, the local branch manager, project engineer, the application engineering staff, and the electronic technicians who would be involved with the supervision, the engineering, and the installation of the control systems. Training and experience of these personnel shall not be less than three years. Failure to disclose this information will be a ground for disqualification of the supplier.

5. Provide a competent and experienced Project Manager employed by the Controls Contractor. The Project Manager shall be supported as necessary by other Contractor employees in order to provide professional engineering, technical and management service for the work. The Project Manager shall attend scheduled Project Meetings as required and shall be empowered to make technical, scheduling and related decisions on behalf of the Controls Contractor.

B. Codes and Standards:

1. All work shall conform to the applicable Codes and Standards.
2. Electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.

1.5 PERFORMANCE

A. The system shall conform to the following:

1. Graphic Display: The system shall display up to four (4) graphics on a single screen with a minimum of twenty (20) dynamic points per graphic. All current data shall be displayed within ten (10) seconds of the request.
2. Graphic Refresh: The system shall update all dynamic points with current data within eight (8) seconds. Data refresh shall be automatic, without operator intervention.
3. Object Command: The maximum time between the command of a binary object by the operator and the reaction by the device shall be two(2) seconds. Analog objects shall start to adjust within two (2) seconds.
4. Object Scan: All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or work-station will be current, within the prior six (6) seconds.
5. Alarm Response Time: The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed (10) seconds.
6. Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every (5) seconds. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control.
7. Multiple Alarm Annunciations: All workstations on the network shall receive alarms within five (5) seconds of each other.

8. Performance: Programmable Controllers shall be able to execute DDC PID control loops at a selectable frequency from at least once every one (1) second. The controller shall scan and update the process value and output generated by this calculation at this same frequency.
9. Reporting Accuracy: Listed below are minimum acceptable reporting end-to-end accuracies for all values reported by the specified system:

Measured Variable	Reported Accuracy
Space temperature	±1°F)
Ducted air temperature	±1°F
Outdoor air temperature	±2°F
Dew Point	±3°]
Water temperature	±1°F
Relative humidity	±2% RH
Water flow	±1% of reading
Air flow (terminal)	±10% of reading
Air flow (measuring stations)	±5% of reading
Air pressure (ducts)	±0.1"w.c.
Air pressure (space)	±0.001"w.c.
Water pressure	±2% of full scale *Note 1
Electrical Power	±0.5% of reading

Note 1: for both absolute and differential pressure

10. Control stability and accuracy: Control sequences shall maintain measured variable at setpoint within the following tolerances:

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±0.2 in. w.g.	0-6 in. w.g.
Air Pressure	±0.01 in. w.g.	-0.1 to 0.1 in. w.g.
Airflow	±10% of full scale	
Space Temperature	±2.0°F	
Duct Temperature	±3°F	
Humidity	±5% RH	
Fluid Pressure	±1.5 psi	1-150 psi
Fluid Pressure	±1.0 in. w.g.	0-50 in. w.g. differential

11. Extent of direct digital control: control design shall allow for at least the points indicated on the points lists on the drawings.

1.6 WARRANTY

- A. Labor and materials for control systems shall be warranted for a period as specified under Warranty in FAR clause 52.246-21.
- B. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no cost or reduction in service to the owner. The system includes all computer equipment, transmission equipment, and all sensors and control devices.
- C. Controls and Instrumentation subcontractor shall be responsible for temporary operations and maintenance of the control systems during the construction period until final commissioning, training of facility operators and acceptance of the project by VA.

1.7 SUBMITTALS

- A. Submit shop drawings in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.
- B. Manufacturer's literature and data for all components including the following:
 - 1. A wiring diagram for each type of input device and output device including DDC controllers, modems, repeaters, etc. Diagram shall show how the device is wired and powered, showing typical connections at the digital controllers and each power supply, as well as the device itself. Show for all field connected devices, including but not limited to, control relays, motor starters, electric or electronic actuators, and temperature pressure, flow and humidity sensors and transmitters.

2. A diagram of each terminal strip, including digital controller terminal strips, terminal strip location, termination numbers and the associated point names.
3. Control dampers and control valves schedule, including the size and pressure drop.
4. Catalog cut sheets of all equipment used. This includes, but is not limited to software (by manufacturer and by third parties), DDC controllers, panels, peripherals, airflow measuring stations and associated components, and auxiliary control devices such as sensors, actuators, and control dampers. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted. Each submitted piece of literature and drawings should clearly reference the specification and/or drawings that it supposed to represent.
5. Sequence of operations for each HVAC system and the associated control diagrams. Equipment and control labels shall correspond to those shown on the drawings.
6. Color prints of proposed graphics with a list of points for display.
7. Furnish a BACnet Protocol Implementation Conformance Statement (PICS) for each BACnet-compliant device.
8. Schematic wiring diagrams for all control, communication and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers and functions. Show all interface wiring to the control system.
9. 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.
10. Riser diagrams of wiring between central control unit and all control panels.
11. Scaled plan drawings showing routing of LAN and locations of control panels, controllers, routers, gateways, ECC, and larger controlled devices.
12. Construction details for all installed conduit, cabling, raceway, cabinets, and similar. Construction details of all penetrations and their protection.

13. Quantities of submitted items may be reviewed but are the responsibility of the contractor administered by this Section of the technical specifications.
- C. Product Certificates: Compliance with Article, QUALITY ASSURANCE.
 - D. Licenses: Provide licenses for all software residing on and used by the Controls Systems and transfer these licenses to the Owner prior to completion.
 - E. As Built Control Drawings:
 1. Furnish three (3) copies of as-built drawings for each control system. The documents shall be submitted for approval prior to final completion.
 2. Furnish one (1) stick set of applicable control system prints for each mechanical system for wall mounting. The documents shall be submitted for approval prior to final completion.
 3. Furnish one (1) CD-ROM in CAD DWG and/or .DXF format for the drawings noted in subparagraphs above.
 - F. Operation and Maintenance (O/M) Manuals):
 1. Submit in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS.
 2. Include the following documentation:
 - a. General description and specifications for all components, including logging on/off, alarm handling, producing trend reports, overriding computer control, and changing set points and other variables.
 - b. Detailed illustrations of all the control systems specified for ease of maintenance and repair/replacement procedures, and complete calibration procedures.
 - c. One copy of the final version of all software provided including operating systems, programming language, operator workstation software, and graphics software.
 - d. Complete troubleshooting procedures and guidelines for all systems.
 - e. Complete operating instructions for all systems.
 - f. Recommended preventive maintenance procedures for all system components including a schedule of tasks for inspection, cleaning and calibration. Provide a list of recommended spare parts needed to minimize downtime.

- g. Training Manuals: Submit the course outline and training material to the Owner for approval three (3) weeks prior to the training to VA facility personnel. These persons will be responsible for maintaining and the operation of the control systems, including programming. The Owner reserves the right to modify any or all of the course outline and training material.
- h. Licenses, guaranty, and other pertaining documents for all equipment and systems.

G. Submit Performance Report to Resident Engineer prior to final inspection.

1.8 INSTRUCTIONS

A. Instructions to VA operations personnel: Perform in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS, and as noted below. Contractor shall also video tape instruction sessions noted below.

1. First Phase: Formal instructions to the VA facilities personnel for a total of 8 hours, conducted sometime between the completed installation and prior to the performance test period of the control system, at a time mutually agreeable to the Contractor and the VA.
2. Second Phase: This phase of training shall comprise of on the job training during start-up, checkout period, and performance test period. VA facilities personnel will work with the Contractor's installation and test personnel on a daily basis during start-up and checkout period.
3. The O/M Manuals shall contain approved submittals as outlined in Article 1.7, SUBMITTALS. The Controls subcontractor will review the manual contents with VA facilities personnel during second phase of training.
4. Training shall be given by direct employees of the controls system subcontractor.

1.9 PROJECT CONDITIONS (ENVIRONMENTAL CONDITIONS OF OPERATION)

- A. The peripheral devices and system support equipment shall be designed to operate in ambient condition of 65 to 90°F at a relative humidity of 20 to 80% non-condensing.
- B. The CUs used outdoors shall be mounted in NEMA 4 waterproof enclosures, and shall be rated for operation at 40 to 150°F.
- C. All electronic equipment shall operate properly with power fluctuations of plus 10 percent to minus 15 percent of nominal supply voltage.

D. Sensors and controlling devices shall be designed to operate in the environment, which they are sensing or controlling.

1.10 APPLICABLE PUBLICATIONS

- A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.
- B. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
 - Standard 135-10.....BACNET Building Automation and Control Networks
- C. American Society of Mechanical Engineers (ASME):
 - B16.18-01.....Cast Copper Alloy Solder Joint Pressure Fittings.
 - B16.22-01.....Wrought Copper and Copper Alloy Solder Joint Pressure Fittings.
- D. American Society of Testing Materials (ASTM):
 - B32-08.....Standard Specification for Solder Metal
 - B88-09.....Standard Specifications for Seamless Copper Water Tube
 - B88M-09.....Standard Specification for Seamless Copper Water Tube (Metric)
 - B280-08.....Standard Specification for Seamless Copper Tube for Air-Conditioning and Refrigeration Field Service
 - D2737-03.....Standard Specification for Polyethylene (PE) Plastic Tubing
- E. Federal Communication Commission (FCC):
 - Rules and Regulations Title 47 Chapter 1-2001 Part 15: Radio Frequency Devices.
- F. Institute of Electrical and Electronic Engineers (IEEE):
 - 802.3-11.....Information Technology-Telecommunications and Information Exchange between Systems-Local and Metropolitan Area Networks- Specific Requirements-Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access method and Physical Layer Specifications
- G. National Fire Protection Association (NFPA):
 - 70-11.....National Electric Code
 - 90A-09.....Standard for Installation of Air-Conditioning and Ventilation Systems
- H. Underwriter Laboratories Inc (UL):
 - 94-10.....Tests for Flammability of Plastic Materials for Parts and Devices and Appliances
 - 294-10.....Access Control System Units
 - 486A/486B-10.....Wire Connectors

555S-11.....	Standard for Smoke Dampers
916-10.....	Energy Management Equipment
1076-10.....	Proprietary Burglar Alarm Units and Systems

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Use new products that the manufacturer is currently manufacturing and that have been installed in a minimum of 25 installations. Spare parts shall be available for at least five years after completion of this contract.

2.2 CONTROLS SYSTEM ARCHITECTURE

- A. All new controllers, panels, etc. shall be integrated by Johnson Controls into the existing JCI architecture.

2.3 COMMUNICATION

- A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135-2008, BACnet.
 - 1. The Data link / physical layer protocol (for communication) acceptable to the VA throughout its facilities is Ethernet (ISO 8802-3) and BACnet/IP.
 - 2. The MS/TP data link / physical layer protocol is not acceptable to the VA in any new BACnet network or sub-network.
- B. Each controller shall have a communication port for connection to an operator interface.
- C. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
 - 1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, reports, system software, and custom programs shall be viewable and editable from each internetwork controller.
 - 2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute specified control system operation. An authorized operator shall be able to edit cross-controller links by typing a standard object address.

- D. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring. Expansion shall not require operator interface hardware additions or software revisions.
- E. ECCs and Controllers with real-time clocks shall use the BACnet Time Synchronization service. The system shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight savings and standard time as applicable.

2.4 ENGINEERING CONTROL CENTER (ECC)

- A. All new controllers, panels, etc. shall be connected and integrated by Johnson Controls to the existing Johnson Controls to the existing Johnson Controls front end workstation.

2.5 BACNET PROTOCOL ANALYZER

- A. For ease of troubleshooting and maintenance, provide a BACnet protocol analyzer. Provide its associated fittings, cables and appurtenances, for connection to the communications network. The BACnet protocol analyzer shall be able to, at a minimum: capture and store to a file all data traffic on all network levels; measure bandwidth usage; filter out (ignore) selected traffic.

2.6 NETWORK AND DEVICE NAMING CONVENTION

A. Network Numbers

1. BACnet network numbers shall be based on a "facility code, network" concept. The "facility code" is the VAMC's or VA campus' assigned numeric value assigned to a specific facility or building. The "network" typically corresponds to a "floor" or other logical configuration within the building. BACnet allows 65535 network numbers per BACnet internet work.
2. The network numbers are thus formed as follows: "Net #" = "FFFNN" where:
 - a. FFF = Facility code (see below)
 - b. NN = 00-99 This allows up to 100 networks per facility or building

B. Device Instances

1. BACnet allows 4194305 unique device instances per BACnet internet work. Using Agency's unique device instances are formed as follows: "Dev #" = "FFFNNDD" where
 - a. FFF and N are as above and

- b. DD = 00-99, this allows up to 100 devices per network.
- 2. Note Special cases, where the network architecture of limiting device numbering to DD causes excessive subnet works. The device number can be expanded to DDD and the network number N can become a single digit. In NO case shall the network number N and the device number D exceed 4 digits.
- 3. Facility code assignments:
- 4. 000-400 Building/facility number
- 5. Note that some facilities have a facility code with an alphabetic suffix to denote wings, related structures, etc. The suffix will be ignored. Network numbers for facility codes above 400 will be assigned in the range 000-399.

C. Device Names

- 1. Name the control devices based on facility name, location within a facility, the system or systems that the device monitors and/or controls, or the area served. The intent of the device naming is to be easily recognized. Names can be up to 254 characters in length, without embedded spaces. Provide the shortest descriptive, but unambiguous, name. For example, in building #123 prefix the number with a "B" followed by the building number, if there is only one chilled water pump "CHWP-1", a valid name would be "B123.CHWP.1.STARTSTOP". If there are two pumps designated "CHWP-1", one in a basement mechanical room (Room 0001) and one in a penthouse mechanical room (Room PH01), the names could be "B123.R0001.CHWP.1.STARTSTOP" or "B123.RPH01.CHWP.1.STARTSTOP". In the case of unitary controllers, for example a VAV box controller, a name might be "B123.R101.VAV". These names should be used for the value of the "Object_Name" property of the BACnet Device objects of the controllers involved so that the BACnet name and the EMCS name are the same.

2.7 BACNET DEVICES

- A. All BACnet Devices - controllers, gateways, routers, actuators and sensors shall conform to BACnet Device Profiles and shall be BACnet Testing Laboratories (BTL) -Listed as conforming to those Device Profiles. Protocol Implementation Conformance Statements (PICSS), describing the BACnet capabilities of the Devices shall be published and available of the Devices through links in the BTL website.

1. BACnet Building Controllers, historically referred to as NACs, shall conform to the BACnet B-BC Device Profile, and shall be BTL-Listed as conforming to the B-BC Device Profile. The Device's PICS shall be submitted.
2. BACnet Advanced Application Controllers shall conform to the BACnet B-AAC Device Profile, and shall be BTL-Listed as conforming to the B-AAC Device Profile. The Device's PICS shall be submitted.
3. BACnet Application Specific Controllers shall conform to the BACnet B-ASC Device Profile, and shall be BTL-Listed as conforming to the B-ASC Device Profile. The Device's PICS shall be submitted.
4. BACnet Smart Actuators shall conform to the BACnet B-SA Device Profile, and shall be BTL-Listed as conforming to the B-SA Device Profile. The Device's PICS shall be submitted.
5. BACnet Smart Sensors shall conform to the BACnet B-SS Device Profile, and shall be BTL-Listed as conforming to the B-SS Device Profile. The Device's PICS shall be submitted.
6. BACnet routers and gateways shall conform to the BACnet B-OTH Device Profile, and shall be BTL-Listed as conforming to the B-OTH Device Profile. The Device's PICS shall be submitted.

2.8 CONTROLLERS

- A. General. Provide an adequate number of BTL-Listed B-BC building controllers and an adequate number of BTL-Listed B-AAC advanced application controllers to achieve the performance specified in the Part 1 Article on "System Performance." Each of these controllers shall meet the following requirements.
 1. The controller shall have sufficient memory to support its operating system, database, and programming requirements.
 2. The building controller shall share data with the ECC and the other networked building controllers. The advanced application controller shall share data with its building controller and the other networked advanced application controllers.
 3. The operating system of the controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
 4. Controllers that perform scheduling shall have a real-time clock.

5. The controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall:
 - a. assume a predetermined failure mode, and
 - b. generate an alarm notification.
 6. The controller shall communicate with other BACnet devices on the internetwork using the BACnet Read (Execute and Initiate) and Write (Execute and Initiate) Property services.
 7. Communication.
 - a. Each controller shall reside on a BACnet network using the ISO 8802-3 (Ethernet) Data Link/Physical layer protocol for its communications. Each building controller also shall perform BACnet routing if connected to a network of custom application and application specific controllers.
 - b. The controller shall provide a service communication port using BACnet Data Link/Physical layer protocol for connection to a portable operator's terminal.
 8. Keypad. A local keypad and display shall be provided for each controller. The keypad shall be provided for interrogating and editing data. Provide a system security password shall be available to prevent unauthorized use of the keypad and display.
 9. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
 10. Memory. The controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
 11. The controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Controller operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 3 ft.
- B. Provide BTL-Listed B-ASC application specific controllers for each piece of equipment for which they are constructed. Application specific controllers shall communicate with other BACnet devices on the internetwork using the BACnet Read (Execute) Property service.
1. Each B-ASC shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.

2. Each B-ASC will contain sufficient I/O capacity to control the target system.
3. Communication.
 - a. Each controller shall reside on a BACnet network using the ISO 8802-3 (Ethernet) Data Link/Physical layer protocol for its communications. Each building controller also shall perform BACnet routing if connected to a network of custom application and application specific controllers.
 - b. Each controller shall have a BACnet Data Link/Physical layer compatible connection for a laptop computer or a portable operator's tool. This connection shall be extended to a space temperature sensor port where shown.
4. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
5. Memory. The application specific controller shall use nonvolatile memory and maintain all BIOS and programming information in the event of a power loss.
6. Immunity to power and noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%. Operation shall be protected against electrical noise of 5-120 Hz and from keyed radios up to 5 W at 3 ft.
7. Transformer. Power supply for the ASC must be rated at a minimum of 125% of ASC power consumption and shall be of the fused or current limiting type.

C. Direct Digital Controller Software

1. The software programs specified in this section shall be commercially available, concurrent, multi-tasking operating system and support the use of software application that operates under DOS or Microsoft Windows.
2. All points shall be identified by up to 30-character point name and 16-character point descriptor. The same names shall be used at the ECC.
3. All control functions shall execute within the stand-alone control units via DDC algorithms. The VA shall be able to customize control strategies and sequences of operations defining the appropriate control loop algorithms and choosing the optimum loop parameters.

4. All controllers shall be capable of being programmed to utilize stored default values for assured fail-safe operation of critical processes. Default values shall be invoked upon sensor failure or, if the primary value is normally provided by the central or another CU, or by loss of bus communication. Individual application software packages shall be structured to assume a fail-safe condition upon loss of input sensors. Loss of an input sensor shall result in output of a sensor-failed message at the ECC. Each ACU and RCU shall have capability for local readouts of all functions. The UCUs shall be read remotely.
5. All DDC control loops shall be able to utilize any of the following control modes:
 - a. Two position (on-off, slow-fast) control.
 - b. Proportional control.
 - c. Proportional plus integral (PI) control.
 - d. Proportional plus integral plus derivative (PID) control. All PID programs shall automatically invoke integral wind up prevention routines whenever the controlled unit is off, under manual control of an automation system or time initiated program.
 - e. Automatic tuning of control loops.
6. System Security: Operator access shall be secured using individual password and operator's name. Passwords shall restrict the operator to the level of object, applications, and system functions assigned to him. A minimum of six (6) levels of security for operator access shall be provided.
7. Application Software: The controllers shall provide the following programs as a minimum for the purpose of optimizing energy consumption while maintaining comfortable environment for occupants. All application software shall reside and run in the system digital controllers. Editing of the application shall occur at the ECC or via a portable operator's terminal, when it is necessary, to access directly the programmable unit.
 - a. Power Demand Limiting (PDL): Power demand limiting program shall monitor the building power consumption and limit the consumption of electricity to prevent peak demand charges. PDL shall continuously track the electricity consumption from a pulse input generated at the kilowatt-hour/demand electric meter. PDL shall sample the meter data to continuously forecast the electric

demand likely to be used during successive time intervals. If the forecast demand indicates that electricity usage will likely to exceed a user preset maximum allowable level, then PDL shall automatically shed electrical loads. Once the demand load has met, loads that have been shed shall be restored and returned to normal mode. Control system shall be capable of demand limiting by resetting the HVAC system set points to reduce load while maintaining indoor air quality.

- b. Economizer: An economizer program shall be provided for VAV systems. This program shall control the position of air handler relief, return, and outdoors dampers. The operator shall be able to override the economizer cycle and return to minimum outdoor air operation at any time.
- c. Night Setback/Morning Warm up Control: The system shall provide the ability to automatically adjust set points for this mode of operation.
- d. Optimum Start/Stop (OSS): Optimum start/stop program shall automatically be coordinated with event scheduling. The OSS program shall start HVAC equipment at the latest possible time that will allow the equipment to achieve the desired zone condition by the time of occupancy, and it shall also shut down HVAC equipment at the earliest possible time before the end of the occupancy period and still maintain desired comfort conditions. The OSS program shall consider both outside weather conditions and inside zone conditions. The program shall automatically assign longer lead times for weekend and holiday shutdowns. The program shall poll all zones served by the associated AHU and shall select the warmest and coolest zones. These shall be used in the start time calculation. It shall be possible to assign occupancy start times on a per air handler unit basis. The program shall meet the local code requirements for minimum outdoor air while the building is occupied. Modification of assigned occupancy start/stop times shall be possible via the ECC.
- e. Event Scheduling: Provide a comprehensive menu driven program to automatically start and stop designated points or a group of points according to a stored time. This program shall provide the capability to individually command a point or group of points.

When points are assigned to one common load group it shall be possible to assign variable time advances/delays between each successive start or stop within that group. Scheduling shall be calendar based and advance schedules may be defined up to one year in advance. Advance schedule shall override the day-to-day schedule. The operator shall be able to define the following information:

- 1) Time, day.
 - 2) Commands such as on, off, auto.
 - 3) Time delays between successive commands.
 - 4) Manual overriding of each schedule.
 - 5) Allow operator intervention.
- f. Alarm Reporting: The operator shall be able to determine the action to be taken in the event of an alarm. Alarms shall be routed to the ECC based on time and events. An alarm shall be able to start programs, login the event, print and display the messages. The system shall allow the operator to prioritize the alarms to minimize nuisance reporting and to speed operator's response to critical alarms. A minimum of six (6) priority levels of alarms shall be provided for each point.
- g. Remote Communications: The system shall have the ability to dial out in the event of an alarm to the ECC and alpha-numeric pagers. The alarm message shall include the name of the calling location, the device that generated the alarm, and the alarm message itself. The operator shall be able to remotely access and operate the system using dial up communications. Remote access shall allow the operator to function the same as local access.
- h. Maintenance Management (PM): The program shall monitor equipment status and generate maintenance messages based upon the operators defined equipment run time, starts, and/or calendar date limits. A preventative maintenance alarm shall be printed indicating maintenance requirements based on pre-defined run time. Each preventive message shall include point description, limit criteria and preventative maintenance instruction assigned to that limit. A minimum of 480-character PM shall be provided for each component of units such as air handling units.

2.9 SPECIAL CONTROLLERS

A. Room Differential Pressure Controller: The differential pressure in laboratory rooms, operating rooms and isolation rooms shall be maintained by controlling the quantity of air exhausted from or supplied to the room. A sensor-controller shall measure and control the velocity of air flowing into or out of the room through a sampling tube installed in the wall separating the room from the adjacent space, and display the value on its monitor. The sensor-controller shall meet the following as a minimum:

1. Operating range: -0.25 to +0.25 inches of water column
2. Resolution: 5 percent of reading
3. Accuracy: +/- 10 percent of reading +/- 0.005 inches of water column
4. Analog output: 0-10 VDC or 4-20 ma
5. Operating temperature range: 32°F-120°F

2.10 SENSORS (AIR, WATER AND STEAM)

A. Sensors' measurements shall be read back to the DDC system, and shall be visible by the ECC.

B. Temperature and Humidity Sensors shall be electronic, vibration and corrosion resistant for wall, immersion, and/or duct mounting. Provide all remote sensors as required for the systems.

1. Temperature Sensors: thermistor type for terminal units and Resistance Temperature Device (RTD) with an integral transmitter type for all other sensors.
 - a. Duct sensors shall be rigid or averaging type as shown on drawings. Averaging sensor shall be a minimum of 1 linear ft of sensing element for each sq ft of cooling coil face area.
 - b. Immersion sensors shall be provided with a separable well made of stainless steel, bronze or monel material. Pressure rating of well is to be consistent with the system pressure in which it is to be installed.
 - c. Space sensors shall be equipped with in-space User set-point adjustment, override switch, numerical temperature display on sensor cover, and communication port. Match room thermostats. Provide a tooled-access cover.
 - 1) Public space sensor: setpoint adjustment shall be only through the ECC or through the DDC system's diagnostic device/laptop. Do not provide in-space User set-point adjustment. Provide an

- opaque keyed-entry cover if needed to restrict in-space User set-point adjustment.
- 2) Psychiatric patient room sensor: sensor shall be flush with wall, shall not include an override switch, numerical temperature display on sensor cover, shall not include a communication port and shall not allow in-space User set-point adjustment. Setpoint adjustment shall be only through the ECC or through the DDC system's diagnostic device/laptop. Provide a stainless steel cover plate with an insulated back and security screws.
 - d. Outdoor air temperature sensors shall have watertight inlet fittings and be shielded from direct sunlight.
 - e. Room security sensors shall have stainless steel cover plate with insulated back and security screws.
 - f. Wire: Twisted, shielded-pair cable.
 - g. Output Signal: 4-20 ma.
 2. Humidity Sensors: Bulk polymer sensing element type.
 - a. Duct and room sensors shall have a sensing range of 20 to 80 percent with accuracy of ± 2 to ± 5 percent RH, including hysteresis, linearity, and repeatability.
 - b. Outdoor humidity sensors shall be furnished with element guard and mounting plate and have a sensing range of 0 to 100 percent RH.
 - c. 4-20 ma continuous output signal.
 - C. Static Pressure Sensors: Non-directional, temperature compensated.
 1. 4-20 ma output signal.
 2. 0 to 5 inches wg for duct static pressure range.
 3. 0 to 0.25 inch wg for Building static pressure range.
 - D. Water flow sensors:
 1. Type: Insertion vortex type with retractable probe assembly and 2 inch full port gate valve.
 - a. Pipe size: 3 to 24 inches.
 - b. Retractor: ASME threaded, non-rising stem type with hand wheel.
 - c. Mounting connection: 2 inch 150 PSI flange.
 - d. Sensor assembly: Design for expected water flow and pipe size.
 - e. Seal: Teflon (PTFE).
 2. Controller:
 - a. Integral to unit.

- b. Locally display flow rate and total.
- c. Output flow signal to BMCS: Digital pulse type.
- 3. Performance:
 - a. Turndown: 20:1
 - b. Response time: Adjustable from 1 to 100 seconds.
 - c. Power: 24 volt DC
- 4. Install flow meters according to manufacturer's recommendations.
Where recommended by manufacturer because of mounting conditions, provide flow rectifier.
- E. Water Flow Sensors: shall be insertion turbine type with turbine element, retractor and preamplifier/transmitter mounted on a two-inch full port isolation valve; assembly easily removed or installed as a single unit under line pressure through the isolation valve without interference with process flow; calibrated scale shall allow precise positioning of the flow element to the required insertion depth within plus or minus 0.05 inch; wetted parts shall be constructed of stainless steel. Operating power shall be nominal 24 VDC. Local instantaneous flow indicator shall be LED type in NEMA 4 enclosure with 3-1/2 digit display, for wall or panel mounting.
 - 1. Performance characteristics:
 - a. Ambient conditions: 40°F to 140°F, 5 to 100% humidity.
 - b. Operating conditions: 125 psig, 30°F to 250°F, 0.5 to 40 feet per second velocity.
 - c. Nominal range (turn down ratio): 10 to 1.
 - d. Preamplifier mounted on meter shall provide 4-20 ma divided pulse output or switch closure signal for units of volume or mass per a time base. Signal transmission distance shall be a minimum of 6,000 feet. Preamplifier for bi-directional flow measurement shall provide a directional contact closure from a relay mounted in the preamplifier
 - e. Pressure Loss: Maximum 1 percent of the line pressure in line sizes above 4 inches.
 - f. Ambient temperature effects, less than 0.005 percent calibrated span per F° temperature change.
 - g. RFI effect - flow meter shall not be affected by RFI.
 - h. Power supply effect less than 0.02 percent of span for a variation of plus or minus 10 percent power supply.

F. Flow switches:

1. Shall be either paddle or differential pressure type.
 - a. Paddle-type switches (liquid service only) shall be UL Listed, SPDT snap-acting, adjustable sensitivity with NEMA 4 enclosure.
 - b. Differential pressure type switches (air or water service) shall be UL listed, SPDT snap acting, NEMA 4 enclosure, with scale range and differential suitable for specified application.

G. Current Switches: Current operated switches shall be self powered, solid state with adjustable trip current as well as status, power, and relay command status LED indication. The switches shall be selected to match the current of the application and output requirements of the DDC systems.

2.11 CONTROL CABLES

A. General:

1. Ground cable shields, drain conductors, and equipment to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments. Comply with Sections 27 05 26 and 26 05 26.
2. Cable conductors to provide protection against induction in circuits. Crosstalk attenuation within the System shall be in excess of -80 dB throughout the frequency ranges specified.
3. Minimize the radiation of RF noise generated by the System equipment so as not to interfere with any audio, video, data, computer main distribution frame (MDF), telephone customer service unit (CSU), and electronic private branch exchange (EPBX) equipment the System may service.
4. The as-installed drawings shall identify each cable as labeled, used cable, and bad cable pairs.
5. Label system's cables on each end. Test and certify cables in writing to the VA before conducting proof-of-performance testing. Minimum cable test requirements are for impedance compliance, inductance, capacitance, signal level compliance, opens, shorts, cross talk, noise, and distortion, and split pairs on all cables in the frequency ranges used. Make available all cable installation and test records at demonstration to the VA. All changes (used pair, failed pair, etc.) shall be posted in these records as the change occurs.

6. Power wiring shall not be run in conduit with communications trunk wiring or signal or control wiring operating at 100 volts or less.
- B. Analogue control cabling shall be not less than No. 18 AWG solid, with thermoplastic insulated conductors as specified in Section 26 05 21.
- C. Copper digital communication cable between the ECC and the B-BC and B-AAC controllers shall be 100BASE-TX Ethernet, Category 5e or 6, not less than minimum 24 American Wire Gauge (AWG) solid, Shielded Twisted Pair (STP) or Unshielded Twisted Pair (UTP), with thermoplastic insulated conductors, enclosed in a thermoplastic outer jacket, as specified in Section 27 15 00.
 1. Other types of media commonly used within IEEE Std 802.3 LANs (e.g., 10Base-T and 10Base-2) shall be used only in cases to interconnect with existing media.
- D. Optical digital communication fiber, if used, shall be Multimode or Singlemode fiber, 62.5/125 micron for multimode or 10/125 micron for singlemode micron with SC or ST connectors as specified in TIA-568-C.1. Terminations, patch panels, and other hardware shall be compatible with the specified fiber and shall be as specified in Section 27 15 00. Fiber-optic cable shall be suitable for use with the 100Base-FX or the 100Base-SX standard (as applicable) as defined in IEEE Std 802.3.

2.12 THERMOSTATS AND HUMIDISTATS

- A. Room thermostats controlling unitary standalone heating and cooling devices not connected to the DDC system shall have three modes of operation (heating - null or dead band - cooling). Thermostats for patient bedrooms shall have capability of being adjusted to eliminate null or dead band. Wall mounted thermostats shall have setpoint range and temperature display and external adjustment:
 1. Electronic Thermostats: Solid-state, microprocessor based, programmable to daily, weekend, and holiday schedules.
 - a. Public Space Thermostat: Public space thermostat shall have a thermistor sensor and shall not have a visible means of set point adjustment. Adjustment shall be via the digital controller to which it is connected.
 - b. Patient Room Thermostats: thermistor with in-space User set point adjustment and an on-casing room temperature numerical temperature display.
 - c. Psychiatric Patient Room Sensors: Electronic duct sensor as noted under Article 2.4.

- d. Battery replacement without program loss.
- B. Freezestats shall have a minimum of one linear foot of sensing element for each 0.093 square meter (one square foot) of coil area. A freezing condition at any increment of one foot anywhere along the sensing element shall be sufficient to operate the thermostatic element. Freezestats shall be manually-reset.
- C. Room Humidistats: Provide fully proportioning humidistat with adjustable throttling range for accuracy of settings and conservation. The humidistat shall have set point scales shown in percent of relative humidity located on the instrument. Systems showing moist/dry or high/low are not acceptable.

2.13 FINAL CONTROL ELEMENTS AND OPERATORS

- A. Fail Safe Operation: Control valves and dampers shall provide "fail safe" operation in either the normally open or normally closed position as required for freeze, moisture, and smoke or fire protection.
- B. Spring Ranges: Range as required for system sequencing and to provide tight shut-off.
- C. Smoke Dampers and Combination Fire/Smoke Dampers: Dampers and operators are specified in Section 23 31 00, HVAC DUCTS AND CASINGS. Control of these dampers is specified under this Section.
- D. Control Valves:
 - 1. Valves shall be rated for a minimum of 150 percent of system operating pressure at the valve location but not less than 125 psig.
 - 2. Valves 2 inches and smaller shall be bronze body with threaded or flare connections.
 - 3. Valves 2 1/2 inches and larger shall be bronze or iron body with flanged connections.
 - 4. Brass or bronze seats except for valves controlling media above 210 degrees F, which shall have stainless steel seats.
 - 5. Flow characteristics:
 - a. Three way modulating valves shall be globe pattern. Position versus flow relation shall be linear relation for steam or equal percentage for water flow control.
 - b. Two-way modulating valves shall be globe pattern. Position versus flow relation shall be linear for steam and equal percentage for water flow control.
 - c. Two-way 2-position valves shall be ball, gate or butterfly type.

6. Maximum pressure drop:
 - a. Two position steam control: 20 percent of inlet gauge pressure.
 - b. Modulating Steam Control: 80 percent of inlet gauge pressure (acoustic velocity limitation).
 - c. Modulating water flow control, greater of 10 feet of water or the pressure drop through the apparatus.
 7. Two position water valves shall be line size.
- E. Damper and Valve Operators and Relays:
1. Pneumatic operators, spring return type with non-ferrous metal bellows or diaphragm of neoprene or other elastomer. Bellows or diaphragm shall be of sufficient size so that a change in operating pressure of not more than two (2) percent of the total motor operating pressure range will be required to start the valve or damper moving. Provide positive positioning or sequencing relays with adjustable operating range and starting point for operators sequenced with other operators to permit adjustment of control sequences, except for control valves in confined spaces in terminal units, which may use springs with range selected to provide necessary sequencing. Metal parts shall be aluminum, mill finish galvanized steel, or zinc plated steel or stainless steel.
 2. Electric operator shall provide full modulating control of dampers and valves. A linkage and pushrod shall be furnished for mounting the actuator on the damper frame internally in the duct or externally in the duct or externally on the duct wall, or shall be furnished with a direct-coupled design. Metal parts shall be aluminum, mill finish galvanized steel, or zinc plated steel or stainless steel. Provide actuator heads which allow for electrical conduit attachment. The motors shall have sufficient closure torque to allow for complete closure of valve or damper under pressure. Provide multiple motors as required to achieve sufficient close-off torque.
 - a. Minimum valve close-off pressure shall be equal to the system pump's dead-head pressure, minimum 50 psig for valves smaller than 4 inches.
 3. Electronic damper operators: Metal parts shall be aluminum, mill finish galvanized steel, or zinc plated steel or stainless steel. Provide actuator heads which allow for electrical conduit attachment. The motors shall have sufficient closure torque to allow

for complete closure of valve or damper under pressure. Provide multiple motors as required to achieve sufficient close-off torque.

- a. VAV Box actuator shall be mounted on the damper axle or shall be of the air valve design, and shall provide complete modulating control of the damper. The motor shall have a closure torque of 35-inch pounds minimum with full torque applied at close off to attain minimum leakage.
4. See drawings for required control operation.

2.14 AIR FLOW CONTROL

- A. Airflow and static pressure shall be controlled via digital controllers with inputs from airflow control measuring stations and static pressure inputs as specified. Controller outputs shall be analog or pulse width modulating output signals. The controllers shall include the capability to control via simple proportional (P) control, proportional plus integral (PI), proportional plus integral plus derivative (PID), and on-off. The airflow control programs shall be factory-tested programs that are documented in the literature of the control manufacturer.
- B. Static Pressure Measuring Station: shall consist of one or more static pressure sensors and transmitters along with relays or auxiliary devices as required for a complete functional system. The span of the transmitter shall not exceed two times the design static pressure at the point of measurement. The output of the transmitter shall be true representation of the input pressure with plus or minus 0.1 inch W.G. of the true input pressure:
 1. Static pressure sensors shall have the same requirements as Airflow Measuring Devices except that total pressure sensors are optional, and only multiple static pressure sensors positioned on an equal area basis connected to a network of headers are required.
 2. For systems with multiple major trunk supply ducts, furnish a static pressure transmitter for each trunk duct. The transmitter signal representing the lowest static pressure shall be selected and this shall be the input signal to the controller.
 3. The controller shall receive the static pressure transmitter signal and CU shall provide a control output signal to the supply fan capacity control device. The control mode shall be proportional plus integral (PI) (automatic reset) and where required shall also include derivative mode.

4. In systems with multiple static pressure transmitters, provide a switch located near the fan discharge to prevent excessive pressure during abnormal operating conditions. High-limit switches shall be manually-reset.

C. Airflow Synchronization:

1. Controls contractor to provide building pressure sensor(s) as required to provide a complete functional system that will maintain a constant outside air flow rate difference between supply and return air to an accuracy of $\pm 10\%$.
2. The total flow signals from supply and return air shall be the input signals to the CU. This CU shall track the return air fan capacity in proportion to the supply air flow under all conditions.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Examine project plans for control devices and equipment locations; and report any discrepancies, conflicts, or omissions to Resident Engineer for resolution before proceeding for installation.
2. Install equipment, piping, wiring /conduit parallel to or at right angles to building lines.
3. Install all equipment and piping in readily accessible locations. Do not run tubing and conduit concealed under insulation or inside ducts.
4. Mount control devices, tubing and conduit located on ducts and apparatus with external insulation on standoff support to avoid interference with insulation.
5. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
6. Run tubing and wire connecting devices on or in control cabinets parallel with the sides of the cabinet neatly racked to permit tracing.
7. Install equipment level and plum.

B. Electrical Wiring Installation:

1. All wiring cabling shall be installed in conduits. Install conduits and wiring in accordance with Specification Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS. Conduits carrying control wiring and cabling shall be dedicated to the control wiring and cabling: these conduits shall not carry power wiring. Provide

- plastic end sleeves at all conduit terminations to protect wiring from burrs.
2. Install analog signal and communication cables in conduit and in accordance with Division 26. Install digital communication cables in conduit and in accordance with Specification Section 27 15 00, Communications Horizontal Cabling.
 3. Install conduit and wiring between operator workstation(s), digital controllers, electrical panels, indicating devices, instrumentation, miscellaneous alarm points, thermostats, and relays as shown on the drawings or as required under this section.
 4. Install all electrical work required for a fully functional system and not shown on electrical plans or required by electrical specifications. Where low voltage (less than 50 volt) power is required, provide suitable Class B transformers.
 5. Install all system components in accordance with National Electric Code.
 - a. Splices: Splices in shielded and coaxial cables shall consist of terminations and the use of shielded cable couplers. Terminations shall be in accessible locations. Cables shall be harnessed with cable ties.
 - b. Equipment: Fit all equipment contained in cabinets or panels with service loops, each loop being at least 12 inches long. Equipment for fiber optics system shall be rack mounted, as applicable, in ventilated, self-supporting, code gauge steel enclosure. Cables shall be supported for minimum sag.
 - c. Cable Runs: Keep cable runs as short as possible. Allow extra length for connecting to the terminal board. Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter.
 - d. Use vinyl tape, sleeves, or grommets to protect cables from vibration at points where they pass around sharp corners, through walls, panel cabinets, etc.
 6. Conceal cables, except in mechanical rooms and areas where other conduits and piping are exposed.
 7. Permanently label or code each point of all field terminal strips to show the instrument or item served. Color-coded cable with cable diagrams may be used to accomplish cable identification.

8. Grounding: ground electrical systems per manufacturer's written requirements for proper and safe operation.

C. Install Sensors and Controls:

1. Temperature Sensors:

- a. Install all sensors and instrumentation according to manufacturer's written instructions. Temperature sensor locations shall be readily accessible, permitting quick replacement and servicing of them without special skills and tools.
- b. Calibrate sensors to accuracy specified, if not factory calibrated.
- c. Use of sensors shall be limited to its duty, e.g., duct sensor shall not be used in lieu of room sensor.
- d. Install room sensors permanently supported on wall frame. They shall be mounted at 5.0 feet above the finished floor.
- e. Mount sensors rigidly and adequately for the environment within which the sensor operates. Separate extended-bulb sensors form contact with metal casings and coils using insulated standoffs.
- f. Sensors used in mixing plenum, and hot and cold decks shall be of the averaging of type. Averaging sensors shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip.
- g. All pipe mounted temperature sensors shall be installed in wells.
- h. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor reading.
- i. Permanently mark terminal blocks for identification. Protect all circuits to avoid interruption of service due to short-circuiting or other conditions. Line-protect all wiring that comes from external sources to the site from lightning and static electricity.

2. Pressure Sensors:

- a. Install duct static pressure sensor tips facing directly downstream of airflow.
- b. Install high-pressure side of the differential switch between the pump discharge and the check valve.
- c. Install snubbers and isolation valves on steam pressure sensing devices.

3. Actuators:
 - a. Mount and link damper and valve actuators according to manufacturer's written instructions.
 - b. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed position.
 - c. Check operation of valve/actuator combination to confirm that actuator modulates valve smoothly in both open and closed position.
4. Flow Switches:
 - a. Install flow switch according to manufacturer's written instructions.
 - b. Mount flow switch a minimum of 5 pipe diameters up stream and 5 pipe diameters downstream or 2 feet whichever is greater, from fittings and other obstructions.
 - c. Assure correct flow direction and alignment.
 - d. Mount in horizontal piping-flow switch on top of the pipe.
- D. Installation of network:
 1. Ethernet:
 - a. The network shall employ Ethernet LAN architecture, as defined by IEEE 802.3. The Network Interface shall be fully Internet Protocol (IP) compliant allowing connection to currently installed IEEE 802.3, Compliant Ethernet Networks.
 - b. The network shall directly support connectivity to a variety of cabling types. As a minimum provide the following connectivity: 100 Base TX (Category 5e cabling) for the communications between the ECC and the B-BC and the B-AAC controllers.
 2. Third party interfaces: Contractor shall integrate real-time data from building systems by other trades and databases originating from other manufacturers as specified and required to make the system work as one system.
- E. Installation of digital controllers and programming:
 1. Provide a separate digital control panel for each major piece of equipment, such as air handling unit, chiller, pumping unit etc. Points used for control loop reset such as outdoor air, outdoor humidity, or space temperature could be located on any of the remote control units.

2. Provide sufficient internal memory for the specified control sequences and trend logging. There shall be a minimum of 25 percent of available memory free for future use.
3. System point names shall be modular in design, permitting easy operator interface without the use of a written point index.
4. Provide software programming for the applications intended for the systems specified, and adhere to the strategy algorithms provided.
5. Provide graphics for each piece of equipment and floor plan in the building. This includes each chiller, cooling tower, air handling unit, fan, terminal unit, boiler, pumping unit etc. These graphics shall show all points dynamically as specified in the point list.

3.2 SYSTEM VALIDATION AND DEMONSTRATION

- A. As part of final system acceptance, a system demonstration is required (see below). Prior to start of this demonstration, the contractor is to perform a complete validation of all aspects of the controls and instrumentation system.
- B. Validation:
 1. Prepare and submit for approval a validation test plan including test procedures for the performance verification tests. Test Plan shall address all specified functions of the ECC and all specified sequences of operation. Explain in detail actions and expected results used to demonstrate compliance with the requirements of this specification. Explain the method for simulating the necessary conditions of operation used to demonstrate performance of the system. Test plan shall include a test check list to be used by the Installer's agent to check and initial that each test has been successfully completed. Deliver test plan documentation for the performance verification tests to the owner's representative 30 days prior to start of performance verification tests. Provide draft copy of operation and maintenance manual with performance verification test.
 2. After approval of the validation test plan, installer shall carry out all tests and procedures therein. Installer shall completely check out, calibrate, and test all connected hardware and software to insure that system performs in accordance with approved specifications and sequences of operation submitted. Installer shall complete and submit Test Check List.

C. Demonstration:

1. System operation and calibration to be demonstrated by the installer in the presence of the Architect or VA's representative on random samples of equipment as dictated by the Architect or VA's representative. Should random sampling indicate improper commissioning, the owner reserves the right to subsequently witness complete calibration of the system at no addition cost to the VA.
2. Demonstrate to authorities that all required safeties and life safety functions are fully functional and complete.
3. Make accessible, personnel to provide necessary adjustments and corrections to systems as directed by balancing agency.
4. The following witnessed demonstrations of field control equipment shall be included:
 - a. Observe HVAC systems in shut down condition. Check dampers and valves for normal position.
 - b. Test application software for its ability to communicate with digital controllers, operator workstation, and uploading and downloading of control programs.
 - c. Demonstrate the software ability to edit the control program off-line.
 - d. Demonstrate reporting of alarm conditions for each alarm and ensure that these alarms are received at the assigned location, including operator workstations.
 - e. Demonstrate ability of software program to function for the intended applications-trend reports, change in status etc.
 - f. Demonstrate via graphed trends to show the sequence of operation is executed in correct manner, and that the HVAC systems operate properly through the complete sequence of operation, e.g., seasonal change, occupied/unoccupied mode, and warm-up condition.
 - g. Demonstrate hardware interlocks and safeties functions, and that the control systems perform the correct sequence of operation after power loss and resumption of power loss.
 - h. Prepare and deliver to the VA graphed trends of all control loops to demonstrate that each control loop is stable and the set points are maintained.

- i. Demonstrate that each control loop responds to set point adjustment and stabilizes within one (1) minute. Control loop trend data shall be instantaneous and the time between data points shall not be greater than one (1) minute.
5. Witnessed demonstration of ECC functions shall consist of:
- a. Running each specified report.
 - b. Display and demonstrate each data entry to show site specific customizing capability. Demonstrate parameter changes.
 - c. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
 - d. Execute digital and analog commands in graphic mode.
 - e. Demonstrate DDC loop precision and stability via trend logs of inputs and outputs (6 loops minimum).
 - f. Demonstrate EMS performance via trend logs and command trace.
 - g. Demonstrate scan, update, and alarm responsiveness.
 - h. Demonstrate spreadsheet/curve plot software, and its integration with database.
 - i. Demonstrate on-line user guide, and help function and mail facility.
 - j. Demonstrate digital system configuration graphics with interactive upline and downline load, and demonstrate specified diagnostics.
 - k. Demonstrate multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
 - l. Demonstrate class programming with point options of beep duration, beep rate, alarm archiving, and color banding.

----- END -----

SECTION 23 09 25
AIR FLOW MEASURING STATIONS

PART 1 GENERAL

1.1 SUMMARY

- A. Provide all material, equipment and labor required to complete the installation of airflow measuring stations as shown on drawings and specified herein. Only thermal dispersion technology monitors will be acceptable.

1.2 REFERENCES

- A. NFPA 70 – National Electrical Code

1.3 SUBMITTALS

- A. Product Data: Dimensions, electrical requirements, mounting requirements, materials of construction, information indicating compliance with requirements herein.

1.4 WARRANTY

- A. Contract Closeout – As specified in Division 1.
- B. Provide manufacturer's warranty for three (3) years from shipment.

PART 2 PRODUCTS

2.1 OUTSIDE AIR MONITOR – THERMAL DISPERSION TECHNOLOGY

- A. Manufacturers:
 - 1. Ebtron
 - 2. Approved equal.
- B. Each airflow-measuring device shall consist of one or more multi-point airflow measuring probes and a single microprocessor-based transmitter. Each transmitter shall have an LCD display capable of displaying airflow as a velocity or volumetric airflow rate. Each transmitter shall operate on 24 VAC. Transmitter shall have field adjustable gain / offset and digital airflow output signal filter.
- C. Each sensing point shall independently determine the airflow rate, which shall be equally weighted and averaged by the transmitter prior to output. Devices, which average multiple non-linear sensing point signals, are not acceptable. Pitot tube arrays are not acceptable.
- D. A single manufacturer shall provide both the airflow measuring probe(s) and transmitter at a given measurement location.
- E. The calibrated velocity range shall be 0-5,000 FPM.
- F. The operating environmental ranges for the airflow measuring probes shall be -20° F to 160° F, 0-95% RH (non-condensing).

- G. The operating environmental ranges for the transmitter shall be -40° F to 140° F, 0 - 95% RH (non-condensing) protected from the weather.
- H. Each independent sensor shall have a sensing point of +/-2% of reading over the entire operating airflow range and be factory calibrated against standards that are traceable to NIST. Each sensor assembly or sensing point shall have sixteen (16) airflow calibration points.
 - 1. Devices whose accuracy is the combined accuracy of the transmitter and sensor probes must demonstrate that the total accuracy meets the performance requirements of this specification throughout the measurement range.
- I. Probe shall be constructed of aluminum alloy tube with 304 stainless steel mounting bracket. Each sensor assembly or sensing point shall contain two (2) bead-in-glass thermistor probes and Kynar coated wire.
- J. The number of probes and sensor density to match values scheduled.
- K. The manufacturer's authorized representative shall review and approve placement and operating airflow rates for each measurement location indicated on the plans. A written report shall be submitted to the project engineer if any measurement locations do not meet manufacturer's placement requirements.
- L. Transmitter output to the host controls shall be one of the following:
 - 1. RS-485: BACNet MS/TP Master or Johnson Controls N2 Bus
 - 2. 10 Base-T Ethernet: Field selectable ModBus TCP and TCP/IP
- M. Airflow measuring devices shall be UL listed as an entire assembly.
- N. Each airflow measuring station to be provided with minimum 10 ft. plenum rated cable for connecting assembly with transmitter.

PART 3 EXECUTION

3.1 PREPARATION

- A. Protect materials and equipment from weather.

3.2 INSTALLATION

- A. Install assemblies per manufacturer's guidelines, with special attention to location of the probes.
- B. Testing and Balancing: Perform testing, adjusting and balancing in accordance with Section 23 05 93, "Testing, Adjusting, and Balancing for HVAC."

----- END -----

SECTION 23 09 26
ROOM PRESSURIZATION CONTROLS

PART 1 GENERAL

1.1 SUMMARY

- A. Related Sections:
 - 1. Section 23 09 23 - Airflow Measuring Stations.

1.2 REFERENCES

- A. NFPA 70 - National Electrical Code
- B. UL Listed.

1.3 SUBMITTALS

- A. Shop Drawings, Product Data, and Samples as specified in Division 1.
- B. Product Data: Submit sizes, finish, and type of mounting. Submit schedule of outlets and inlets showing type, size, location, application, and noise level.

1.4 CLOSEOUT SUBMITTALS

- A. Execution and Closeout Requirements as specified in Division 1.

1.5 WARRANTY

- A. Execution and Closeout Requirements as specified in Division 1.
- B. Furnish one year manufacturer warranty for sensors, transmitters, and panels.

PART 2 PRODUCTS

2.1 ROOM PRESSURIZATION CONTROLS

- A. Manufacturers:
 - 1. Ebtron
 - 2. Phoenix Controls
 - 3. TSI
- B. General: Provide system to measure differential pressure between Corridor-Ante Room and Ante Room-Isolation Room. System to include sensors, transmitters, local alarms, and auxiliary display panels.
- C. Sensor: Accuracy +/- 2% reading over range of -0.1 in WC to +0.1 in WC. Heavy duty sensor protected by stainless steel cover. Provide plenum rated cable for connection to transmitter.
- D. Transmitter / Controller: Capable of accepting 4-20 mA or 0-10 Vdc signals. Panel max 12" x 12" size. Controller to provide continuous display of pressure differential to at least 0.0001 in WC. Panel to include audible alarm with silence button. Panel to include LED lights to signal "NORMAL," "CAUTION," and "ALARM" conditions. Panel and

controller to utilize test function. Panel and controller to utilize password protection to prevent tampering with device.

- E. Manufacturer to provide factory calibration report for sensors and controllers to be included in O&M data.

PART 3 EXECUTION

3.1 EXAMINATION

- A. Coordination as specified in Division 1.
- B. Verify wall systems are ready for installation.

3.2 INSTALLATION

- A. Mechanical and general contractors are responsible for coordinating to ensure that pressurization controls are operating properly. If during performance testing it is determined that Ante Room and/or Isolation Room partitions are not adequately sealed, these conditions will be corrected prior to retesting and acceptance of installation.
Mechanical contractor is responsible for coordinating with TAB agent to correct all installation issues with airflows which prevent proper system operation until retesting and acceptance of system are complete.
- B. Install control panel level and flush with wall.

----- END -----

SECTION 23 21 13
HYDRONIC PIPING

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Water piping to connect HVAC equipment, including the following:
 - 1. Chilled water, heating hot water and drain piping.
 - 2. Extension of domestic water make-up piping.

1.2 RELATED WORK

- A. Section 01 00 00, GENERAL REQUIREMENTS.
- B. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.
- C. Section 03 30 00, CAST-IN-PLACE CONCRETE.
- D. Section 13 05 41, SEISMIC RESTRAINT REQUIREMENTS FOR NON-STRUCTURAL COMPONENTS: Seismic restraints for piping.
- E. Section 23 05 11, COMMON WORK RESULTS FOR HVAC: General mechanical requirements and items, which are common to more than one section of Division 23.
- F. Section 23 21 23, HYDRONIC PUMPS: Pumps.
- G. Section 23 07 11, HVAC INSULATION: Piping insulation.
- H. Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC: Temperature and pressure sensors and valve operators.

1.3 QUALITY ASSURANCE

- A. Section 23 05 11, COMMON WORK RESULTS FOR HVAC, which includes welding qualifications.
- B. Submit prior to welding of steel piping a certificate of Welder's certification. The certificate shall be current and not more than one year old.
- C. All grooved joint couplings, fittings, valves, and specialties shall be the products of a single manufacturer. Grooving tools shall be the same manufacturer as the grooved components.
 - 1. All castings used for coupling housings, fittings, valve bodies, etc., shall be date stamped for quality assurance and traceability.

1.4 SUBMITTALS

- A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.
- B. Manufacturer's Literature and Data:
 - 1. Pipe and equipment supports. Submit calculations for variable spring and constant support hangers.
 - 2. Pipe and tubing, with specification, class or type, and schedule.

- B. American National Standards Institute, Inc./Fluid Controls Institute
(ANSI/FCI):
 - 70-2-2006.....Control Valve Seat Leakage
- C. American Society of Mechanical Engineers (ASME):
 - B16.1-98.....Cast Iron Pipe Flanges and Flanged Fittings
 - B16.3-2006.....Malleable Iron Threaded Fittings: Class 150 and
300
 - B16.4-2006.....Gray Iron Threaded Fittings: (Class 125 and
250)
 - B16.5-2003.....Pipe Flanges and Flanged Fittings: NPS ½
through NPS 24 Metric/Inch Standard
 - B16.9-07.....Factory Made Wrought Butt Welding Fittings
 - B16.11-05.....Forged Fittings, Socket Welding and Threaded
 - B16.18-01.....Cast Copper Alloy Solder Joint Pressure
Fittings
 - B16.22-01.....Wrought Copper and Bronze Solder Joint Pressure
Fittings.
 - B16.24-06.....Cast Copper Alloy Pipe Flanges and Flanged
Fittings
 - B16.39-06.....Malleable Iron Threaded Pipe Unions
 - B16.42-06.....Ductile Iron Pipe Flanges and Flanged Fittings
 - B31.1-08.....Power Piping
- D. American Society for Testing and Materials (ASTM):
 - A47/A47M-99 (2004).....Ferritic Malleable Iron Castings
 - A53/A53M-07.....Standard Specification for Pipe, Steel, Black
and Hot-Dipped, Zinc-Coated, Welded and
Seamless
 - A106/A106M-08.....Standard Specification for Seamless Carbon
Steel Pipe for High-Temperature Service
 - A126-04.....Standard Specification for Gray Iron Castings
for Valves, Flanges, and Pipe Fittings
 - A183-03 Standard Specification for Carbon Steel Track
Bolts and Nuts
 - A216/A216M-08 Standard Specification for Steel Castings,
Carbon, Suitable for Fusion Welding, for High
Temperature Service

- A234/A234M-07 Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
- A307-07 Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength
- A536-84 (2004) Standard Specification for Ductile Iron Castings
- A615/A615M-08 Deformed and Plain Carbon Steel Bars for Concrete Reinforcement
- A653/A 653M-08 Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) By the Hot-Dip Process
- B32-08 Standard Specification for Solder Metal
- B62-02 Standard Specification for Composition Bronze or Ounce Metal Castings
- B88-03 Standard Specification for Seamless Copper Water Tube
- B209-07 Aluminum and Aluminum Alloy Sheet and Plate
- C177-04 Standard Test Method for Steady State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded Hot Plate Apparatus
- C478-09 Precast Reinforced Concrete Manhole Sections
- C533-07 Calcium Silicate Block and Pipe Thermal Insulation
- C552-07 Cellular Glass Thermal Insulation
- C591-08 Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
- D1784-08 Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compound
- F. American Water Works Association (AWWA):
- C110-08.....Ductile Iron and Grey Iron Fittings for Water
- C203-02.....Coal Tar Protective Coatings and Linings for Steel Water Pipe Lines Enamel and Tape Hot Applied
- G. American Welding Society (AWS):
- B2.1-02.....Standard Welding Procedure Specification
- H. Copper Development Association, Inc. (CDA):
- CDA A4015-06.....Copper Tube Handbook

- I. Expansion Joint Manufacturer's Association, Inc. (EJMA):
 - EMJA-2003.....Expansion Joint Manufacturer's Association
Standards, Ninth Edition
- J. Manufacturers Standardization Society (MSS) of the Valve and Fitting Industry, Inc.:
 - SP-67-02a.....Butterfly Valves
 - SP-70-06.....Gray Iron Gate Valves, Flanged and Threaded
Ends
 - SP-71-05.....Gray Iron Swing Check Valves, Flanged and
Threaded Ends
 - SP-80-08.....Bronze Gate, Globe, Angle and Check Valves
 - SP-85-02.....Cast Iron Globe and Angle Valves, Flanged and
Threaded Ends
 - SP-110-96.....Ball Valves Threaded, Socket-Welding, Solder
Joint, Grooved and Flared Ends
 - SP-125-00.....Gray Iron and Ductile Iron In-line, Spring
Loaded, Center-Guided Check Valves
- K. Tubular Exchanger Manufacturers Association: TEMA 9th Edition, 2007

1.6 SPARE PARTS

- A. For mechanical pressed sealed fittings provide tools required for each pipe size used at the facility.

PART 2 - PRODUCTS

2.1 PIPE AND FITTINGS

- A. All pipe and fittings to be made in U.S.A.

2.2 PIPE AND TUBING

- A. Chilled Water and Heating Water Piping:
 - 1. Steel: ASTM A53 Grade B, seamless, Schedule 40.
 - 2. Copper: ASTM B88, Type L, hard drawn.
- B. Extension of Domestic Water Make-up Piping: Type L, hard drawn copper tubing.
- C. Cooling Coil Condensate Drain Piping:
 - 1. From air handling units: Copper water tube, ASTM B88, Type M, piping.
- D. Pipe supports, including insulation shields, for above ground piping: Section 23 05 11, COMMON WORK RESULTS FOR HVAC.
- E. Steam Piping: Steel Pipe, ASTM A53/A53M, Schedule 80.
 - 1. Fittings: ASME B16.3, malleable iron Class 250, or ASTM A234/A234M, forged steel welding type, Class 300.

2. Joints: Threaded for pipe 2 inches and smaller; welded for pipe 2-1/2 inches and larger.
3. All flanges in the steam distribution piping to be installed with spiral-wound metallic gasket equal to Garlock FLEXSEAL. Gasket to be manufactured in accordance with ASME B16.20, be rated for 250-
psig, be 304 stainless steel winding material, and have PTFE filler material.

2.3 FITTINGS FOR STEEL PIPE

- A. 2 inches and Smaller: Screwed or welded joints.
 1. Butt welding: ASME B16.9 with same wall thickness as connecting piping.
 2. Screwed: 150 pound malleable iron, ASME B16.3. 125 pound cast iron, ASME B16.4, may be used in lieu of malleable iron. Bushing reduction of a single pipe size, or use of close nipples, is not acceptable.
 3. Unions: ASME B16.39.
 4. Water hose connection adapter: Brass, pipe thread to 3/4 inch garden hose thread, with hose cap nut.
- B. 2-1/2 inches and Larger: Welded or flanged joints. Contractor's option: Grooved mechanical couplings and fittings.
 1. Butt welding fittings: ASME B16.9 with same wall thickness as connecting piping. Elbows shall be long radius type, unless otherwise noted.
 2. Welding flanges and bolting: ASME B16.5:
 - a. Weld neck or slip-on, plain face, with 1/8 inch thick full face, heavy duty neoprene gasket suitable for 220 degrees F.
Contractor's option: Convoluted, cold formed 150 pound steel flanges, with teflon gaskets, may be used for water service.
 - b. Flange bolting: Carbon steel machine bolts or studs and nuts, ASTM A307, Grade B.
 3. Welded Branch and Tap Connections: Forged steel weldolets, or branchlets and threadolets may be used for branch connections up to one pipe size smaller than the main. Forged steel half-couplings, ASME B16.11 may be used for drain, vent and gage connections.
 4. Grooved Mechanical Pipe Couplings and Fittings (Contractor's Option): Grooved Mechanical Pipe Couplings and Fittings by Victaulic or approved equal may be used, with roll grooved pipe in lieu of welded, screwed or flanged connections. All joints must be rigid type.

- a. Grooved mechanical couplings: Ductile iron, ASTM A395, fabricated in two or more parts, securely held together by two or more track-head, square, or oval-neck bolts, ASTM A449 and A183.
- b. Gaskets: Rubber product recommended by the coupling manufacturer for the intended service, rated for -30 deg. F to 230 deg. F.
- c. Grooved end fittings: Ductile iron, ASTM A395; or steel, ASTM A234, designed to accept grooved mechanical couplings. Tap-in type branch connections are acceptable.
- d. Provide with stainless steel bolts, nuts, and washers.

2.4 FITTINGS FOR COPPER TUBING

A. Joints:

1. Solder Joints: Joints shall be made up in accordance with recommended practices of the materials applied. Apply 95/5 tin and antimony on all copper piping.
2. Mechanically formed tee connection in water and drain piping: Form mechanically extracted collars in a continuous operation by drilling pilot hole and drawing out tube surface to form collar, having a height of not less than three times the thickness of tube wall. Adjustable collaring device shall insure proper tolerance and complete uniformity of the joint. Notch and dimple joining branch tube in a single process to provide free flow where the branch tube penetrates the fitting.

B. Bronze Flanges and Flanged Fittings: ASME B16.24.

C. Fittings: ANSI/ASME B16.18 cast copper or ANSI/ASME B16.22 solder wrought copper.

2.5 DIELECTRIC FITTINGS

- A. Provide where copper tubing and ferrous metal pipe are joined.
- B. 2 inches and Smaller: Threaded dielectric union, ASME B16.39.
- C. 2 1/2 inches and Larger: Flange union with dielectric gasket and bolt sleeves, ASME B16.42.
- D. Temperature Rating, 210 degrees F.
- E. Contractor's option: On pipe sizes 2" and smaller, screwed end brass ball valves or dielectric nipples may be used in lieu of dielectric unions.

2.6 SCREWED JOINTS

- A. Pipe Thread: ANSI B1.20.
- B. Lubricant or Sealant: Oil and graphite or other compound approved for the intended service.

2.7 VALVES

A. Manufacturers:

1. Apollo
2. Nibco
3. Milwaukee

B. All valves of the same type shall be products of a single manufacturer.

C. Provide chain operators for valves 6 inches and larger when the centerline is located 8 feet or more above the floor or operating platform.

D. Shut-Off Valves

1. Ball Valves (Pipe sizes 2" and smaller): MSS-SP 110, screwed or solder connections, brass or bronze body with chrome-plated ball with full port and Teflon seat at 400 psig // 600 psig working pressure rating. Provide stem extension to allow operation without interfering with pipe insulation.

2. Butterfly Valves (Pipe Sizes 2-1/2" and larger): Provide stem extension to allow 2 inches of pipe insulation without interfering with valve operation. MSS-SP 67, flange lug type or grooved end rated 175 psig working pressure at 200 degrees F. Valves shall be ANSI Leakage Class VI and rated for bubble tight shut-off to full valve pressure rating. Valve shall be rated for dead end service and bi-directional flow capability to full rated pressure. Not permitted for direct buried pipe applications.

a. Body: Cast iron, ASTM A126, Class B. Malleable iron, ASTM A47 electro-plated, or ductile iron, ASTM A536, Grade 65-45-12 electro-plated.

b. Trim: Bronze, aluminum bronze, or 300 series stainless steel disc, bronze bearings, 316 stainless steel shaft and manufacturer's recommended resilient seat. Resilient seat shall be field replaceable, and fully line the body to completely isolate the body from the product. A phosphate coated steel shaft or stem is acceptable, if the stem is completely isolated from the product.

E. Globe and Angle Valves

1. Globe Valves

a. 2 inches and smaller: MSS-SP 80, bronze, 150 lb. Globe valves shall be union bonnet with metal plug type disc.

- b. 2 1/2 inches and larger: 125 psig, flanged, iron body, bronze trim, MSS-SP-85 for globe valves.
- 2. Angle Valves:
 - a. 2 inches and smaller: MSS-SP 80, bronze, 150 lb. Angle valves shall be union bonnet with metal plug type disc.
 - b. 2 1/2 inches and larger: 125 psig, flanged, iron body, bronze trim, MSS-SP-85 for angle.
- F. Check Valves
 - 1. Swing Check Valves:
 - a. 2 inches and smaller: MSS-SP 80, bronze, 150 lb., 45 degree swing disc.
 - b. 2 1/2 inches and larger: 125 psig, flanged, iron body, bronze trim, MSS-SP-71 for check valves.
 - 2. Non-Slam or Silent Check Valve: Spring loaded double disc swing check or internally guided flat disc lift type check for bubble tight shut-off. Provide where check valves are shown in chilled water and hot water piping. Check valves incorporating a balancing feature may be used.
 - a. Body: MSS-SP 125 cast iron, ASTM A126, Class B, or steel, ASTM A216, Class WCB, or ductile iron, ASTM 536, flanged, grooved, or wafer type.
 - b. Seat, disc and spring: 18-8 stainless steel, or bronze, ASTM B62. Seats may be elastomer material.
- G. Water Flow Balancing Valves: For flow regulation and shut-off. Valves shall be line size rather than reduced to control valve size.
 - 1. Ball style valve.
 - 2. A dual purpose flow balancing valve and adjustable flow meter, with bronze or cast iron body, calibrated position pointer, valved pressure taps or quick disconnects with integral check valves and preformed polyurethane insulating enclosure.
 - 3. Provide a readout kit including flow meter, readout probes, hoses, flow charts or calculator, and carrying case.
- H. Automatic Balancing Control Valves: Factory calibrated to maintain constant flow (plus or minus five percent) over system pressure fluctuations of at least 10 times the minimum required for control. Provide standard pressure taps and four sets of capacity charts. Valves shall be line size and be one of the following designs:

1. Gray iron (ASTM A126) or brass body rated 175 psig at 200 degrees F, with stainless steel piston and spring.
2. Brass or ferrous body designed for 300 psig service at 250 degrees F, with corrosion resistant, tamper proof, self-cleaning piston/spring assembly that is easily removable for inspection or replacement.
3. Combination assemblies containing ball type shut-off valves, unions, flow regulators, strainers with blowdown valves and pressure temperature ports shall be acceptable.

2.8 WATER FLOW MEASURING DEVICES

- A. Minimum overall accuracy plus or minus three percent over a range of 70 to 110 percent of design flow. Select devices for not less than 110 percent of design flow rate.
- B. Venturi Type: Bronze, steel, or cast iron with bronze throat, with valved pressure sensing taps upstream and at the throat.
- C. Wafer Type Circuit Sensor: Cast iron wafer-type flow meter equipped with readout valves to facilitate the connecting of a differential pressure meter. Each readout valve shall be fitted with an integral check valve designed to minimize system fluid loss during the monitoring process.
- D. Flow Measuring Device Identification:
 1. Metal tag attached by chain to the device.
 2. Include meter or equipment number, manufacturer's name, meter model, flow rate factor and design flow rate in gpm.

2.9 STRAINERS

- A. Y Type.
 1. Screens: Bronze, monel metal or 18-8 stainless steel, free area not less than 2-1/2 times pipe area, with perforations as follows: 0.045 inch diameter perforations for 4 inches and larger: 0.125 inch diameter perforations.
- B. Suction Diffusers: Specified in Section 23 21 23, HYDRONIC PUMPS.

2.10 FLEXIBLE CONNECTORS

- A. Flanged Spool Connector:
 1. Single arch or multiple arch type. Tube and cover shall be constructed of chlorobutyl elastomer with full faced integral flanges to provide a tight seal without gaskets. Connectors shall be internally reinforced with high strength synthetic fibers

impregnated with rubber or synthetic compounds as recommended by connector manufacturer, and steel reinforcing rings.

2. Working pressures and temperatures shall be as follows:
 - a. Connector sizes 2 inches to 4 inches, 165 psig at 250 degrees F.
 - b. Connector sizes 5 inches to 12 inches, 140 psig at 250 degrees F.
3. Provide ductile iron retaining rings and control units.

B. Mechanical Pipe Couplings:

See other fittings specified under Part 2, PRODUCTS.

2.11 EXPANSION JOINTS

- A. Factory built devices, inserted in the pipe lines, designed to absorb axial cyclical pipe movement which results from thermal expansion and contraction. This includes factory-built or field-fabricated guides located along the pipe lines to restrain lateral pipe motion and direct the axial pipe movement into the expansion joints.
- B. Manufacturing Quality Assurance: Conform to Expansion Joints Manufacturers Association Standards.
- C. Bellows - Internally Pressurized Type:
 1. Multiple corrugations of Type 304 or Type A240-321 stainless steel.
 2. Internal stainless steel sleeve entire length of bellows.
 3. External cast iron equalizing rings for services exceeding 50 psig.
 4. Welded ends.
 5. Design shall conform to standards of EJMA and ASME B31.1.
 6. External tie rods designed to withstand pressure thrust force upon anchor failure if one or both anchors for the joint are at change in direction of pipeline.
 7. Integral external cover.
- D. Bellows - Externally Pressurized Type:
 1. Multiple corrugations of Type 304 stainless steel.
 2. Internal and external guide integral with joint.
 3. Design for external pressurization of bellows to eliminate squirm.
 4. Welded ends.
 5. Conform to the standards of EJMA and ASME B31.1.
 6. Threaded connection at bottom, one inch minimum, for drain or drip point.
 7. Integral external cover and internal sleeve.
- E. Expansion Compensators:
 1. Corrugated bellows, externally pressurized, stainless steel or bronze.

2. Internal guides and anti-torque devices.
 3. Threaded ends.
 4. External shroud.
 5. Conform to standards of EJMA.
- F. Expansion Joint (Contractor's Option): 350 psig maximum working pressure, steel pipe fitting consisting of telescoping body and slip-pipe sections, PTFE modified polyphenylene sulfide coated slide section, with grooved ends, suitable for axial end movement to 3 inch.
- G. Expansion Joint Identification: Provide stamped brass or stainless steel nameplate on each expansion joint listing the manufacturer, the allowable movement, flow direction, design pressure and temperature, date of manufacture, and identifying the expansion joint by the identification number on the contract drawings.
- H. Guides: Provide factory-built guides along the pipe line to permit axial movement only and to restrain lateral and angular movement. Guides must be designed to withstand a minimum of 15 percent of the axial force which will be imposed on the expansion joints and anchors. Field-built guides may be used if detailed on the contract drawings.
- I. Supports: Provide saddle supports and frame or hangers for heat exchanger. Mounting height shall be adjusted to facilitate gravity return of steam condensate. Construct supports from steel, weld joints.

2.12 HYDRONIC SYSTEM COMPONENTS

- A. Tangential Air Separator: ASME Pressure Vessel Code construction for 125 psig working pressure, flanged tangential inlet and outlet connection, internal perforated stainless steel air collector tube designed to direct released air into expansion tank, bottom blowdown connection. Provide Form No. U-1. If scheduled on the drawings, provide a removable stainless steel strainer element having 3/16 inch perforations and free area of not less than five times the cross-sectional area of connecting piping.
- B. Diaphragm Type Pre-Pressurized Expansion Tank: ASME Pressure Vessel Code construction for 125 psig working pressure, welded steel shell, rust-proof coated, with a flexible elastomeric diaphragm suitable for a maximum operating temperature of 240 degrees F. Provide Form No. U-1. Tank shall be equipped with system connection, drain connection, standard air fill valve and be factory pre-charged to a minimum of 12 psig.

- C. Pressure Reducing Valve (Water): Diaphragm or bellows operated, spring loaded type, with minimum adjustable range of 4 psig above and below set point. Bronze, brass or iron body and bronze, brass or stainless steel trim, rated 125 psig working pressure at 225 degrees F.
- D. Pressure Relief Valve: Bronze or iron body and bronze or stainless steel trim, with testing lever. Comply with ASME Code for Pressure Vessels, Section 8, and bear ASME stamp.
- E. Automatic Air Vent Valves (where shown): Cast iron or semi-steel body, 150 psig working pressure, stainless steel float, valve, valve seat and mechanism, minimum 1/2 inch water connection and 1/4 inch air outlet. Air outlet shall be piped to the nearest floor drain.

2.13 WATER FILTERS AND POT CHEMICAL FEEDERS

See section 23 25 00, HVAC WATER TREATMENT, Article 2.2, CHEMICAL TREATMENT FOR CLOSED LOOP SYSTEMS.

2.14 GAGES, PRESSURE AND COMPOUND

- A. ASME B40.100, Accuracy Grade 1A, liquid-filled, (pressure, vacuum, or compound for air, oil or water), initial mid-scale accuracy 1 percent of scale (Qualify grade), metal or phenolic case, 4-1/2 inches in diameter, 1/4 inch NPT bottom connection, white dial with black graduations and pointer, clear glass or acrylic plastic window, suitable for board mounting. Provide red "set hand" to indicate normal working pressure.
- B. Provide brass lever handle union cock. Provide brass/bronze pressure snubber for gages in water service.
- C. Range of Gages: Provide range equal to at least 130 percent of normal operating range.

2.15 PRESSURE/TEMPERATURE TEST PROVISIONS

- A. Pete's Plug: 1/4 inch MPT by 3 inches long, brass body and cap, with retained safety cap, nordel self-closing valve cores, permanently installed in piping where shown, or in lieu of pressure gage test connections shown on the drawings.
- B. Provide one each of the following test items to the Resident Engineer:
 - 1. 1/4 inch FPT by 1/8 inch diameter stainless steel pressure gage adapter probe for extra long test plug. PETE'S 500 XL is an example.
 - 2. 3-1/2 inch diameter, one percent accuracy, compound gage, 30 inches Hg to 100 psig range.
 - 3. 220 degrees F pocket thermometer one-half degree accuracy, one inch dial, 5 inch long stainless steel stem, plastic case.

2.16 THERMOMETERS

- A. Mercury or organic liquid filled type, red or blue column, clear plastic window, with 6 inch brass stem, straight, adjustable angle as required for each in reading.
- B. Case: Chrome plated brass or aluminum with enamel finish.
- C. Scale: Not less than 9 inches, range as described below, two degree graduations.
- D. Separable Socket (Well): Brass, extension neck type to clear pipe insulation.
- E. Scale ranges:
 - 1. Chilled Water: 30-80 degrees F.
 - 2. Hot Water: 60-240 degrees F.

2.17 FIRESTOPPING MATERIAL

Refer to Section 23 05 11, COMMON WORK RESULTS FOR HVAC and STEAM GENERATION.

2.18 ELECTRICAL HEAT TRACING SYSTEMS

- A. Systems shall meet requirements of the National Electrical Code (NEC), Section 427.
- B. Provide tracing for outdoor piping subject to freezing temperatures Below 38 degrees F as follows:
 - 1. Chilled water exposed to the weather.
- C. Heating Cable: Flexible, parallel circuit construction consisting of a continuous self-limiting resistance, conductive inner core material between two parallel copper bus wires, designed for cut-to-length at the job site and for wrapping around valves and complex fittings. Self-regulation shall prevent overheating and burnouts even where the cable overlaps itself.
 - 1. Provide end seals at ends of circuits. Wire at the ends of the circuits is not to be tied together.
 - 2. Provide sufficient cable, as recommended by the manufacturer, to keep the pipe surface at 36 degrees F minimum during winter outdoor design temperature, but not less than the following:
 - a. 3 inch pipe and smaller with 1 inch thick insulation: 4 watts per foot of pipe.
 - b. 4 inch pipe and larger 1-1/2 inch thick insulation: 8 watts per feet of pipe.
- D. Electrical Heating Tracing Accessories:

1. Power supply connection fitting and stainless steel mounting brackets. Provide stainless steel worm gear clamp to fasten bracket to pipe.
2. 1/2 inch wide fiberglass reinforced pressure sensitive cloth tape to fasten cable to pipe at 12 inch intervals.
3. Pipe surface temperature control thermostat: Cast aluminum, NEMA 4 (watertight) enclosure, 1/2 inch NPT conduit hub, SPST switch rated 20 amps at 480 volts AC, with capillary and copper bulb sensor. Set thermostat to maintain pipe surface temperature at not less than 34 degrees F.
4. Signs: Manufacturer's standard (NEC Code), stamped "ELECTRIC TRACED" located on the insulation jacket at 10 feet intervals along the pipe on alternating sides.

PART 3 - EXECUTION

3.1 GENERAL

- A. The drawings show the general arrangement of pipe and equipment but do not show all required fittings and offsets that may be necessary to connect pipes to equipment, coils, etc., and to coordinate with other trades. Provide all necessary fittings, offsets and pipe runs based on field measurements and at no additional cost to the government. Coordinate with other trades for space available and relative location of HVAC equipment and accessories to be connected on ceiling grid. Pipe location on the drawings shall be altered by contractor where necessary to avoid interferences and clearance difficulties.
- B. Store materials to avoid excessive exposure to weather or foreign materials. Keep inside of piping relatively clean during installation and protect open ends when work is not in progress.
- C. Support piping securely. Refer to PART 3, Section 23 05 11, COMMON WORK RESULTS FOR HVAC and STEAM GENERATION. Install heat exchangers at height sufficient to provide gravity flow of condensate to the flash tank and condensate pump.
- D. Install piping generally parallel to walls and column center lines, unless shown otherwise on the drawings. Space piping, including insulation, to provide one inch minimum clearance between adjacent piping or other surface. Unless shown otherwise, slope drain piping down in the direction of flow not less than one inch in 40 feet. Provide eccentric reducers to keep bottom of sloped piping flat.

- E. Locate and orient valves to permit proper operation and access for maintenance of packing, seat and disc. Generally locate valve stems in overhead piping in horizontal position. Provide a union adjacent to one end of all threaded end valves. Control valves usually require reducers to connect to pipe sizes shown on the drawing. Install butterfly valves with the valve open as recommended by the manufacturer to prevent binding of the disc in the seat.
- F. Offset equipment connections to allow valving off for maintenance and repair with minimal removal of piping. Provide flexibility in equipment connections and branch line take-offs with 3-elbow swing joints where noted on the drawings.
- G. Tee water piping runouts or branches into the side of mains or other branches. Avoid bull-head tees, which are two return lines entering opposite ends of a tee and exiting out the common side.
- H. Provide manual or automatic air vent at all piping system high points and drain valves at all low points. Install piping to floor drains from all automatic air vents.
- I. Connect piping to equipment as shown on the drawings. Install components furnished by others such as:
 - 1. Water treatment pot feeders and condenser water treatment systems.
 - 2. Flow elements (orifice unions), control valve bodies, flow switches, pressure taps with valve, and wells for sensors.
- J. Thermometer Wells: In pipes 2-1/2 inches and smaller increase the pipe size to provide free area equal to the upstream pipe area.
- K. Firestopping: Fill openings around uninsulated piping penetrating floors or fire walls, with firestop material. For firestopping insulated piping refer to Section 23 07 11, HVAC, PLUMBING, and BOILER PLANT INSULATION.
- L. Where copper piping is connected to steel piping, provide dielectric connections.

3.2 PIPE JOINTS

- A. Welded: Beveling, spacing and other details shall conform to ASME B31.1 and AWS B2.1. See Welder's qualification requirements under "Quality Assurance" in Section 23 05 11, COMMON WORK RESULTS FOR HVAC. All welds to be prime painted.
- B. Screwed: Threads shall conform to ASME B1.20; joint compound shall be applied to male threads only and joints made up so no more than three

threads show. Coat exposed threads on steel pipe with joint compound, or red lead paint for corrosion protection.

- C. Mechanical Joint: Pipe grooving shall be in accordance with joint manufacturer's specifications. Lubricate gasket exterior including lips, pipe ends and housing interiors to prevent pinching the gasket during installation. Lubricant shall be as recommended by coupling manufacturer.
- D. 125 Pound Cast Iron Flange (Plain Face): Mating flange shall have raised face, if any, removed to avoid overstressing the cast iron flange.

3.3 EXPANSION JOINTS

- A. Anchors and Guides: Provide type, quantity and spacing as recommended by manufacturer of expansion joint and as shown. A professional engineer shall verify in writing that anchors and guides are properly designed for forces and moments which will be imposed.
- B. Cold Set: Provide setting of joint travel at installation as recommended by the manufacturer for the ambient temperature during the installation.
- C. Preparation for Service: Remove all apparatus provided to restrain joint during shipping or installation. Representative of manufacturer shall visit the site and verify that installation is proper.
- D. Access: Expansion joints must be located in readily accessible space. Locate joints to permit access without removing piping or other devices. Allow clear space to permit replacement of joints and to permit access to devices for inspection of all surfaces and for adding.

3.4 SEISMIC BRACING ABOVEGROUND PIPING

Provide in accordance with Section 13 05 41, SEISMIC RESTRAINT REQUIREMENTS FOR NON-STRUCTURAL COMPONENTS.

3.5 LEAK TESTING ABOVEGROUND PIPING

- A. Inspect all joints and connections for leaks and workmanship and make corrections as necessary, to the satisfaction of the Resident Engineer. Tests may be either of those below, or a combination, as approved by the Resident Engineer.
- B. An operating test at design pressure, and for hot systems, design maximum temperature.
- C. A hydrostatic test at 1.5 times design pressure. For water systems the design maximum pressure would usually be the static head, or expansion tank maximum pressure, plus pump head. Factory tested equipment

(convertors, exchangers, coils, etc.) need not be field tested. Isolate equipment where necessary to avoid excessive pressure on mechanical seals and safety devices.

3.6 FLUSHING AND CLEANING PIPING SYSTEMS

- A. Water Piping: Clean systems as recommended by the suppliers of chemicals specified Division 23.
1. Initial flushing: Remove loose dirt, mill scale, metal chips, weld beads, rust, and like deleterious substances without damage to any system component. Provide temporary piping or hose to bypass coils, control valves, exchangers and other factory cleaned equipment unless acceptable means of protection are provided and subsequent inspection of hide-out areas takes place. Isolate or protect clean system components, including pumps and pressure vessels, and remove any component which may be damaged. Open all valves, drains, vents and strainers at all system levels. Remove plugs, caps, spool pieces, and components to facilitate early debris discharge from system. Sectionalize system to obtain debris carrying velocity of 6 feet per second, if possible. Connect dead-end supply and return headers as necessary. Flush bottoms of risers. Install temporary strainers where necessary to protect down-stream equipment. Supply and remove flushing water and drainage by various type hose, temporary and permanent piping and Contractor's booster pumps. Flush until clean as approved by the Resident Engineer.
 2. Cleaning: Using products supplied in Division 23, circulate systems at normal temperature to remove adherent organic soil, hydrocarbons, flux, pipe mill varnish, pipe joint compounds, iron oxide, and like deleterious substances not removed by flushing, without chemical or mechanical damage to any system component. Removal of tightly adherent mill scale is not required. Keep isolated equipment which is "clean" and where dead-end debris accumulation cannot occur. Sectionalize system if possible, to circulate at velocities not less than 6 feet per second. Circulate each section for not less than four hours. Blow-down all strainers, or remove and clean as frequently as necessary. Drain and prepare for final flushing.
 3. Final Flushing: Return systems to conditions required by initial flushing after all cleaning solution has been displaced by clean make-up. Flush all dead ends and isolated clean equipment. Gently

operate all valves to dislodge any debris in valve body by throttling velocity. Flush for not less than one hour.

3.7 WATER TREATMENT

- A. Install water treatment equipment and provide water treatment system piping, with chemicals provided by the existing VAMC vendor.
- B. Close and fill system as soon as possible after final flushing to minimize corrosion.
- C. Charge systems with chemicals specified in Section 23 25 00, HVAC WATER TREATMENT.
- D. Utilize this activity, by arrangement with the Resident Engineer, for instructing VA operating personnel.

3.8 ELECTRIC HEAT TRACING

- A. Install tracing as recommended by the manufacturer.
- B. Coordinate electrical connections.

3.9 OPERATING AND PERFORMANCE TEST AND INSTRUCTION

- A. Refer to PART 3, Section 23 05 11, COMMON WORK RESULTS FOR HVAC.
- B. Adjust red set hand on pressure gages to normal working pressure.

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SECTION 23 21 23
HYDRONIC PUMPS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Hydronic pumps for Heating, Ventilating and Air Conditioning.

1.2 RELATED WORK

- A. Section 01 00 00, GENERAL REQUIREMENTS.
- B. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.
- C. Section 13 05 41, SEISMIC RESTRAINT REQUIREMENTS FOR NON-STRUCTURAL COMPONENTS.
- D. Section 23 05 11, COMMON WORK RESULTS FOR HVAC.
- E. Section 23 05 48, VIBRATION ISOLATION AND SEISMIC / WIND CONTROLS FOR HVAC PIPING AND EQUIPMENT.
- F. Section 23 21 13, HYDRONIC PIPING.
- G. Section 23 05 12, GENERAL MOTOR REQUIREMENTS FOR HVAC EQUIPMENT.

1.3 QUALITY ASSURANCE

- A. Refer to Paragraph, QUALITY ASSURANCE, in Section 23 05 11, COMMON WORK RESULTS FOR HVAC.
- B. Design Criteria:
 - 1. Pumps design and manufacturer shall conform to Hydraulic Institute Standards.
 - 2. Pump sizes, capacities, pressures, operating characteristics and efficiency shall be as scheduled.
 - 3. Head-capacity curves shall slope up to maximum head at shut-off. Curves shall be relatively flat for closed systems. Select pumps near the midrange of the curve, so the design capacity falls to the left of the best efficiency point, to allow a cushion for the usual drift to the right in operation, without approaching the pump curve end point and possible cavitation and unstable operation.
 - 4. Pump Driver: Furnish with pump. Size shall be non-overloading at any point on the head-capacity curve.
 - 5. Provide all pumps with motors, impellers, drive assemblies, bearings, coupling guard and other accessories specified. Statically and dynamically balance all rotating parts.

6. Furnish each pump and motor with a nameplate giving the manufacturers name, serial number of pump, capacity in GPM and head in feet at design condition, horsepower, voltage, frequency, speed and full load current and motor efficiency.
 7. Test all pumps before shipment. The manufacturer shall certify all pump ratings.
- C. Allowable Vibration Tolerance for Pump Units: Section 23 05 41, NOISE AND VIBRATION CONTROL FOR HVAC PIPING and EQUIPMENT.

1.4 SUBMITTALS

- A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, and SAMPLES.
- B. Manufacturer's Literature and Data:
 1. Pumps and accessories.
 2. Motors and drives.
 3. Variable speed motor controllers.
- C. Manufacturer's installation, maintenance and operating instructions, in accordance with Section 23 05 11, COMMON WORK RESULTS FOR HVAC and STEAM GENERATION.
- D. Characteristic Curves: Head-capacity, efficiency-capacity, brake horsepower-capacity, and NPSHR-capacity for each pump and for combined pumps in parallel or series service. Identify pump and show fluid pumped, specific gravity, pump speed and curves plotted from zero flow to maximum for the impeller being furnished and at least the maximum diameter impeller that can be used with the casing.

1.5 APPLICABLE PUBLICATIONS

- A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only:
- B. American Iron and Steel Institute (AISI):

AISI 1045.....Cold Drawn Carbon Steel Bar, Type 1045

AISI 416.....Type 416 Stainless Steel
- C. American National Standards Institute (ANSI):

ANSI B15.1-00(R2008)..... Safety Standard for Mechanical Power
Transmission Apparatus

ANSI B16.1-05.....Cast Iron Pipe Flanges and Flanged Fittings,
Class 25, 125, 250 and 800

D. American Society for Testing and Materials (ASTM):

A48-03 (2008).....Standard Specification for Gray Iron Castings

B62-2009.....Standard Specification for Composition Bronze or
Ounce Metal Castings

E. Maintenance and Operating Manuals in accordance with Section 01 00 00,
General Requirements.

1.6 DEFINITIONS

A. Capacity: Gallons per minute (GPM) of the fluid pumped.

B. Head: Total dynamic head in feet of the fluid pumped.

C. Flat head-capacity curve: Where the shutoff head is less than 1.16 times
the head at the best efficiency point.

1.7 SPARE MATERIALS

A. Furnish one spare seal and casing gasket for each pump to the Resident
Engineer.

PART 2 - PRODUCTS

2.1 CENTRIFUGAL PUMPS, BRONZE FITTED

A. General:

1. Manufacturers:

- a. Bell and Gossett
- b. Paco
- c. Taco
- d. Aurora
- e. Weinman

2. Provide pumps that will operate continuously without overheating
bearings or motors at every condition of operation on the pump curve,
or produce noise audible outside the room or space in which
installed.

3. Provide pumps of size, type and capacity as indicated, complete with
electric motor and drive assembly. Design pump casings for the
indicated working pressure and factory test at 1½ times the designed
pressure.

4. Provide pumps of the same type, the product of a single manufacturer, with pump parts of the same size and type interchangeable.
5. General Construction Requirements
 - a. Balance: Rotating parts, statically and dynamically.
 - b. Construction: To permit servicing without breaking piping or motor connections.
 - c. Pump Motors: Provide NEMA premium efficiency, inverter duty motors. Refer to Section 23 05 12, GENERAL MOTOR REQUIREMENTS FOR HVAC EQUIPMENT. Motors shall be Open Drip Proof and operate at 1750 rpm unless noted otherwise.
 - d. Heating pumps shall be suitable for handling water to 225°F.
 - e. Provide coupling guards that meet ANSI B15.1, Section 8 and OSHA requirements.
 - f. Pump Connections: Flanged.
 - g. Pump shall be factory tested.
6. Variable Speed Pumps:
 - a. The pumps shall be the type shown on the drawings and specified herein flex coupled to an open drip-proof motor.
 - b. Variable Speed Motor Controllers: Refer to Section 26 29 11, LOW-VOLTAGE MOTOR STARTERS and to Section 23 05 11, COMMON WORK RESULTS FOR HVAC and STEAM GENERATION paragraph, Variable Speed Motor Controllers. Furnish controllers with pumps and motors.
 - c. Pump operation and speed control shall be as shown on the drawings.
- B. Base Mounted End Suction Type:
 1. Casing and Bearing Housing: Close-grained cast iron, ASTM A48.
 2. Casing Wear Rings: Bronze.
 3. Suction and Discharge: Plain face flange, 125 psig, ANSI B16.1.
 4. Casing Vent: Manual brass cock at high point.
 5. Casing Drain and Gage Taps: 1/2-inch plugged connections minimum size.
 6. Impeller: Bronze, ASTM B62, enclosed type, keyed to shaft.
 7. Shaft: Steel, AISI Type 1045 or stainless steel.
 8. Shaft Seal: Manufacturer's standard mechanical type to suit pressure and temperature and fluid pumped.
 9. Shaft Sleeve: Bronze or stainless steel.
 10. Motor: Furnish with pump. Refer to Section 23 05 12, GENERAL MOTOR REQUIREMENTS FOR HVAC EQUIPMENT.
 11. Base Mounted Pumps:
 - a. Designed for disassembling for service or repair without disturbing the piping or removing the motor.

- b. Impeller Wear Rings: Bronze.
 - c. Shaft Coupling: Non-lubricated steel flexible type or spacer type with coupling guard, ANSI B15.1, bolted to the baseplate.
 - d. Base: Cast iron or fabricated steel for common mounting to a concrete base.
12. Suction Diffuser:
- a. Body: Cast iron with steel inlet vanes and combination diffuser-strainer-orifice cylinder with 3/16-inch diameter openings for pump protection. Provide taps for strainer blowdown and gage connections.
 - b. Provide adjustable foot support for suction piping.
 - c. Strainer free area: Not less than five times the suction piping.
 - d. Provide disposable start-up strainer.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Follow manufacturer's written instructions for pump mounting and start-up. Access/Service space around pumps shall not be less than minimum space recommended by pumps manufacturer.
- B. Provide drains for bases and seals for base mounted pumps, piped to and discharging into floor drains.
- C. Coordinate location of thermometer and pressure gauges as per Section 23 21 13, HYDRONIC PIPING.
- D. Ensure weight of piping near pump is independently supported and not bearing on pump assembly.

3.2 START-UP

- A. Verify that the piping system has been flushed, cleaned and filled.
- B. Lubricate pumps before start-up.
- C. Prime the pump, vent all air from the casing and verify that the rotation is correct. To avoid damage to mechanical seals, never start or run the pump in dry condition.
- D. Verify that correct size heaters-motor over-load devices are installed for each pump controller unit.
- E. Field modifications to the bearings and or impeller (including trimming) are not permitted. If the pump does not meet the specified vibration

tolerance send the pump back to the manufacturer for a replacement pump.
All modifications to the pump shall be performed at the factory.

- F. Ensure the disposable strainer is free of debris prior to testing and balancing of the hydronic system.
- G. Prior to TAB, replace the disposable start-up strainer with a regular strainer in the suction diffuser.
- H. Check shaft alignment prior to startup and document for project record.

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